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Cereals Straw Resources for bioenergy in the European Union



Pamplona, 18-19 October 2006



2007

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Proceedings of the Expert Consultation

“Cereals Straw Resources for Bioenergy in the European Union”

Joint Research Centre of the European Commission IES JRC (www.jrc.cec.eu.int)
CENER, National Renewable Energy Centre of Spain, (www.cener.com)

**Pamplona, Spain
14-15 October 2006.**

Acknowledgements

This Expert Consultation on “Cereals straw resources for bioenergy in the European Union” was held at the CENER Headquarters in Pamplona (Spain) on 14 and 15 October 2006. The organisers of the meeting were *J.F.Dallemand (Renewable Energies Unit, Institute for Environment and Sustainability, Joint Research Centre, European Commission)*, *I. Echeverría Goñi (National Centre for Renewable Energies, CENER, Spain)* and *D.Sánchez González (National Centre for Renewable Energies, CENER, Spain)*. The Proceedings were prepared by J.F.Dallemand and the organisers acknowledge the input from all the participants (see detailed list in Annex) and from the chairs, co-chairs, and rapporteurs: *H.P.Piörr (University of Applied Sciences, Eberswalde, Germany)*, *D.Powlson, (Rothamsted Research, United Kingdom)*, *F.Labalette (GIE ARVALIS/ONIDOL, France)*, *D.Schieder (Technical University of Munich, Germany)*, *T.Wiesenthal (European Commission, Joint Research Centre, Institute for Prospective Technological Studies, W.Elbersen, (Wageningen University, Netherlands))*. Special thanks to *P. Lerga, Acciona Energia* and the Sanguesa team for their participation and the organisation of the technical visit.


The contribution of *C.Panoutsou (Imperial College, London)* during the phase of meeting preparation has been highly appreciated as well as the link to the JEC Well to Wheels study on future automotive fuels and powertrains in the European context provided by *R.Edwards (Renewable Energies Unit, Institute for Environment and Sustainability, Joint Research Centre, European Commission)*. This meeting was possible thanks to the support of *H.Ossenbrink* and *A.Jaeger-Waldau (Renewable Energies Unit, Institute for Environment and Sustainability, Joint Research Centre, European Commission)* within the framework of the activities of the Scientific and Technical Reference System on Renewable Energy and Energy End Use Efficiency (STRS RE & EEE). The digital version of the Proceedings can be found on the STRS RE & EEE web site (<http://streference.jrc.cec.eu.int/>).

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INTRODUCTION

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GIS-based assessment of cereal straw energy in the European Union

Robert A.H. Edwards, Marcel Šuri, Thomas A. Huld, Jean Francois Dallemand


European Commission, Joint research Centre
Institute for Environment and Sustainability, Renewable Energies, Ispra, Italy

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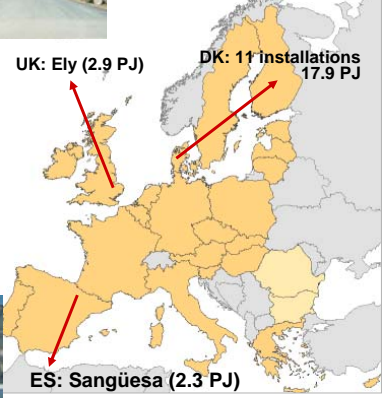
Straw energy today in EU25+2

- abundant throughout Europe
- easy to exploit
- scalable technology

however...

- bigger installations only in DK, UK and ES
- slow transfer of know-how to other regions
- 'pan-European' approach missing







UK: Ely (2.9 PJ) DK: 11 installations 17.9 PJ ES: Sangüesa (2.3 PJ)

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Straw energy potential is high

Decision making is hampered, because...

- terminology and methodologies not harmonized
- lack of comparable data
- little information below national level
- potential often not linked to the technology options
- interrelation of factors not considered and decisions are site sensitive:
 - * resource/demand pattern
 - * conflicts of interests
 - * logistics

Straw energy assessments (PJ):

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Objectives

Inventory of straw from wheat and barley in EU25+2

- actual production
- environmental constraints
- competitive use
- availability for energy

-> data disaggregation

Suitability for large scale electricity generation

- example of Ely power station (UK, 38MW)
- economics
- suitability maps
- localization/optimization

Resolve spatially-determined issues

- how much resource, where
- what technology
- at what cost

Assist to policy- and decision-making

Ongoing study – first results

... from tables to maps

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Data/tools

Eurostat Newcronos (NUTS2 regions), year 2003

- agricultural crops
- cattle
- land use

GIS data

- GISCO
- CORINE Land Cover 2000

Geographical Information System (GIS)

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Straw inventory

Actual production Environmental constraints Competitive use Availability for energy

wheat & barley production
(1000 tonnes/region, year 2003)

+

→

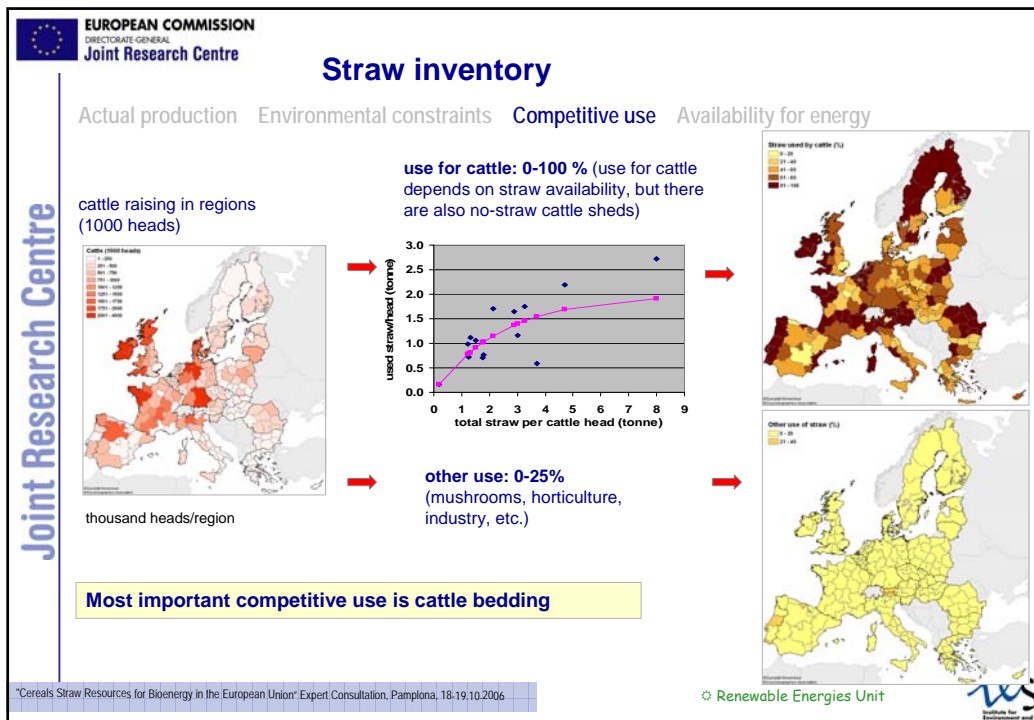
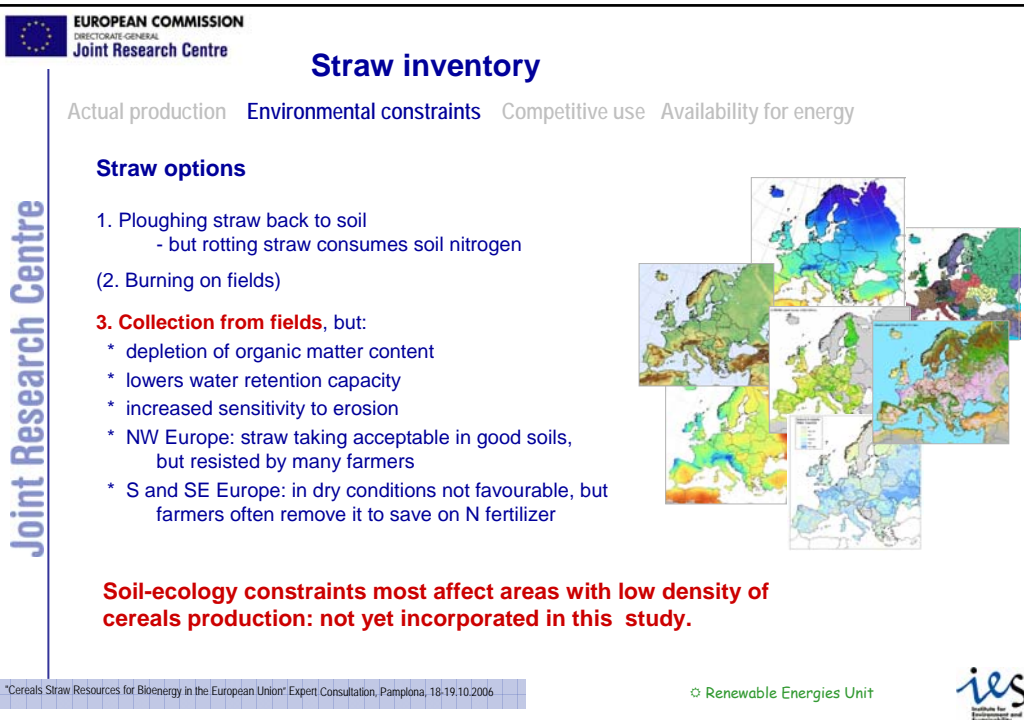
straw/grain = from 0.62 to 0.94
based on grain yield

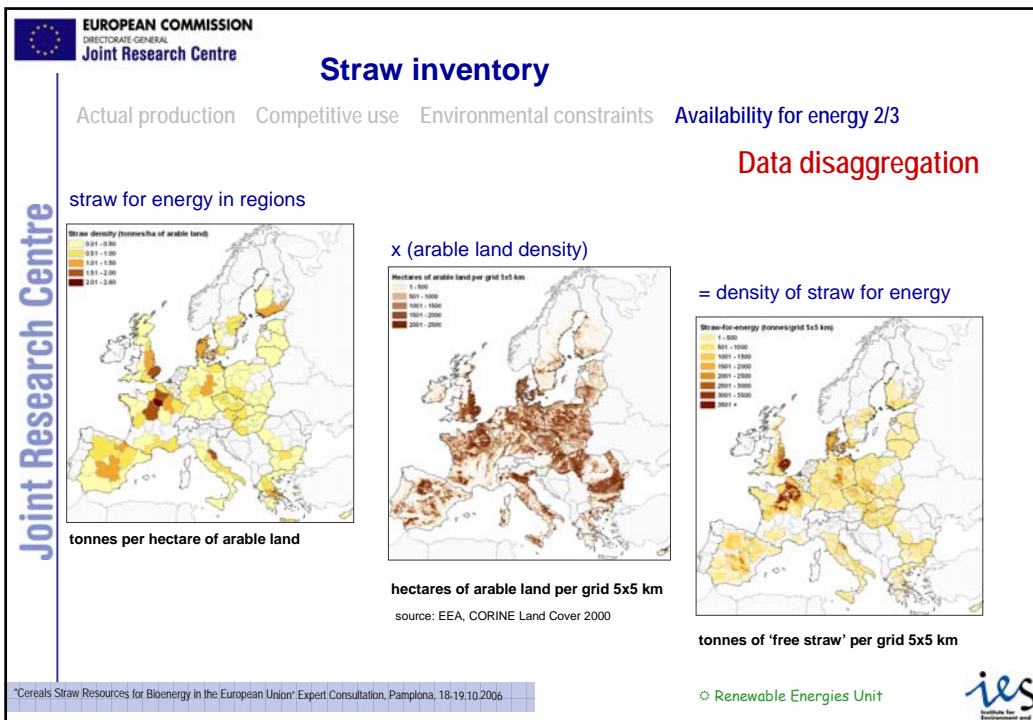
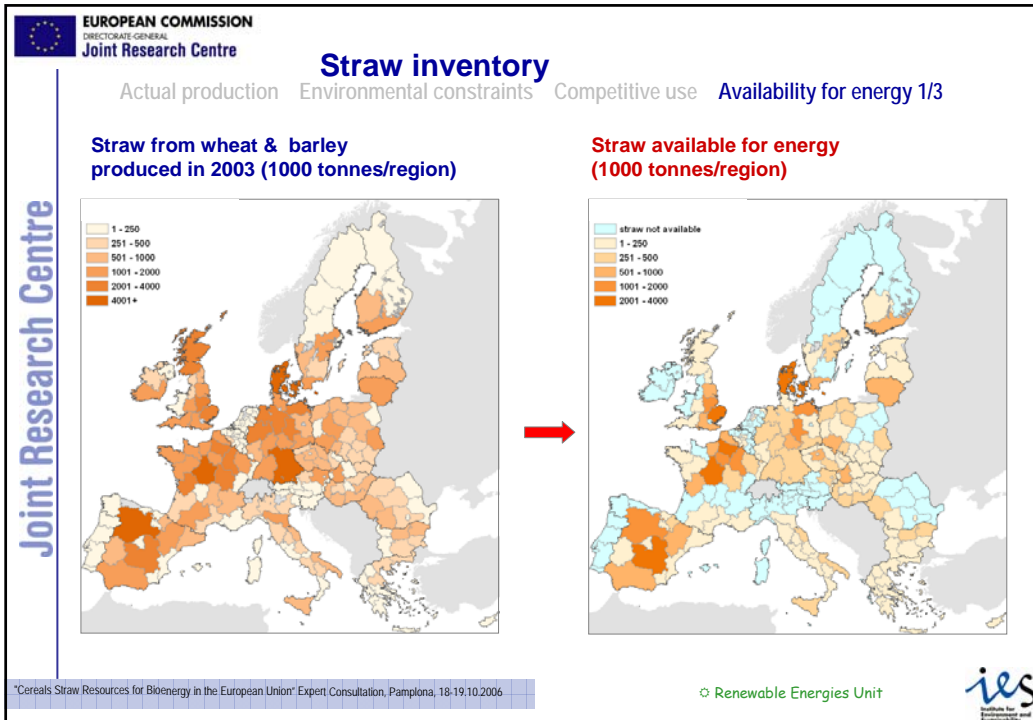
Straw production (1000 tonnes/region)

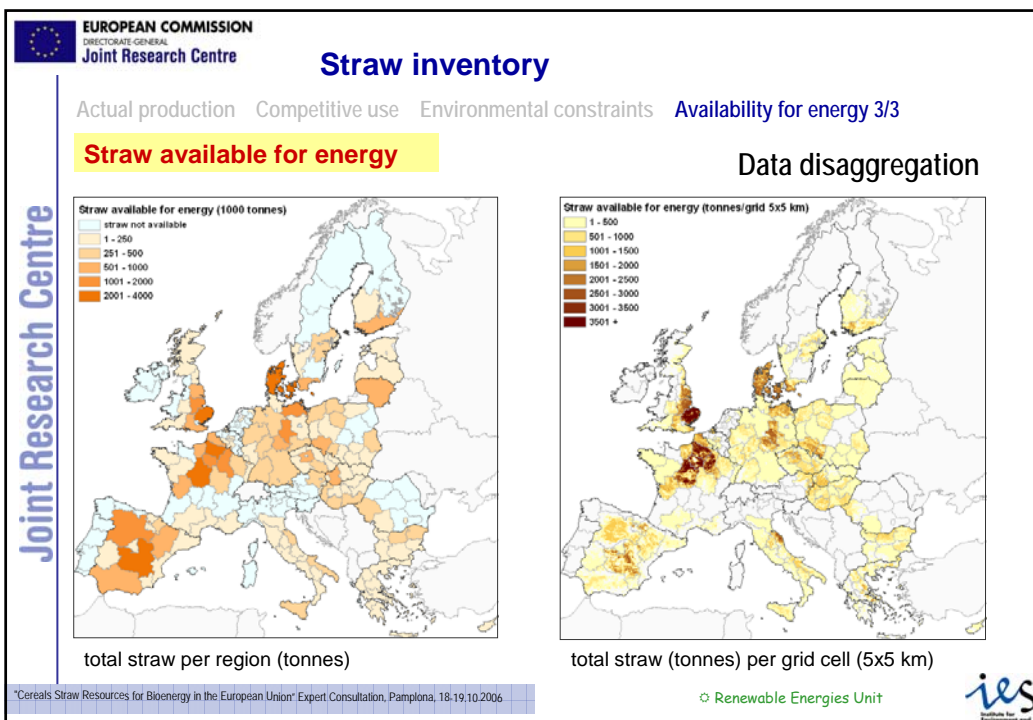
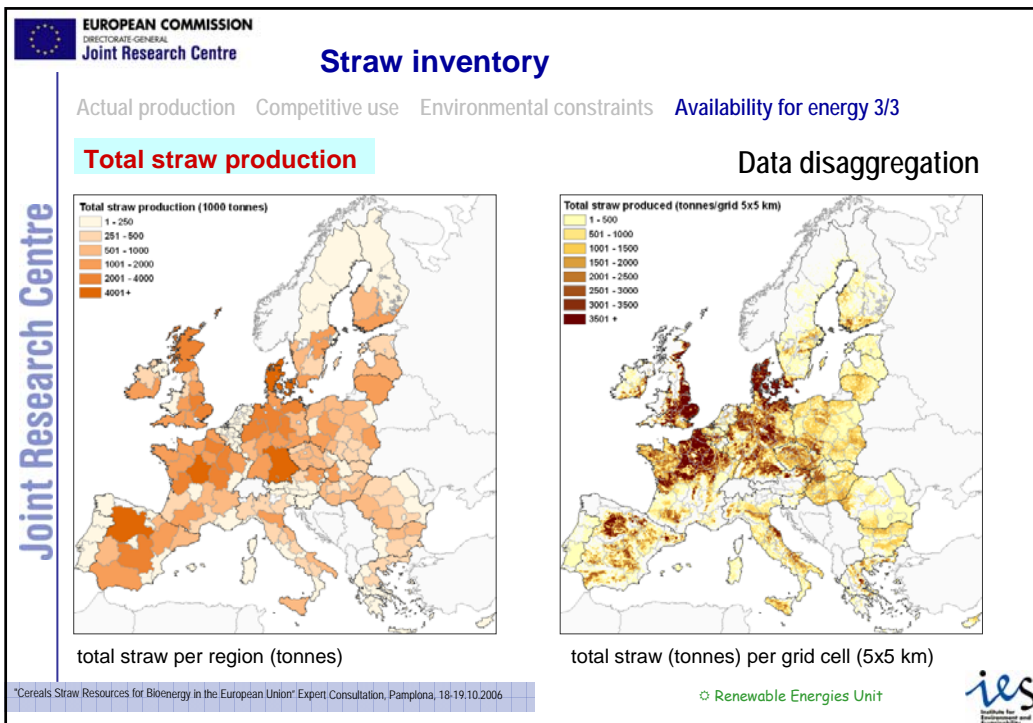
source: Eurostat NewCronos 2003

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Suitability for large scale electricity generation

Ely power station Economics Suitability maps Localization Optimization

Much of our projection is based on

Ely power station (UK)

World's biggest straw electricity power plant
(in operation since 2000)

- grate boiler with steam turbine
- yearly consumption:
 - 200 000 tons straw
 - + 6% natural gas energy
- straw collected within the distance up to 50 km
- 38 MW_{el}
- plant efficiency 32%
- load factor 90%

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Suitability for large scale electricity generation

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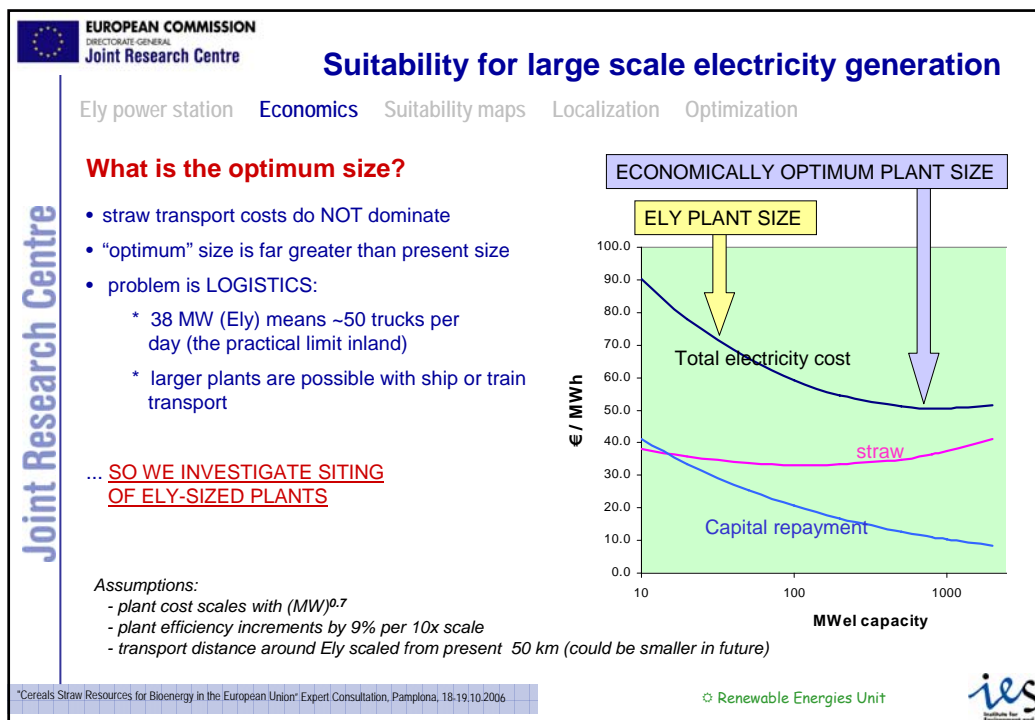
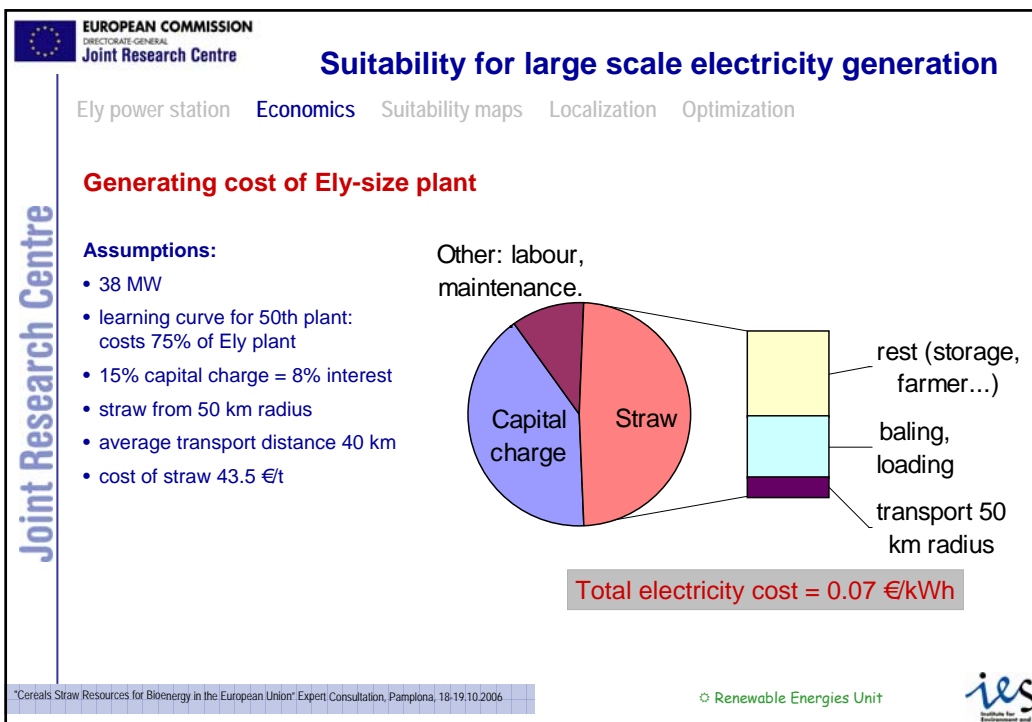
Ely power station (UK)

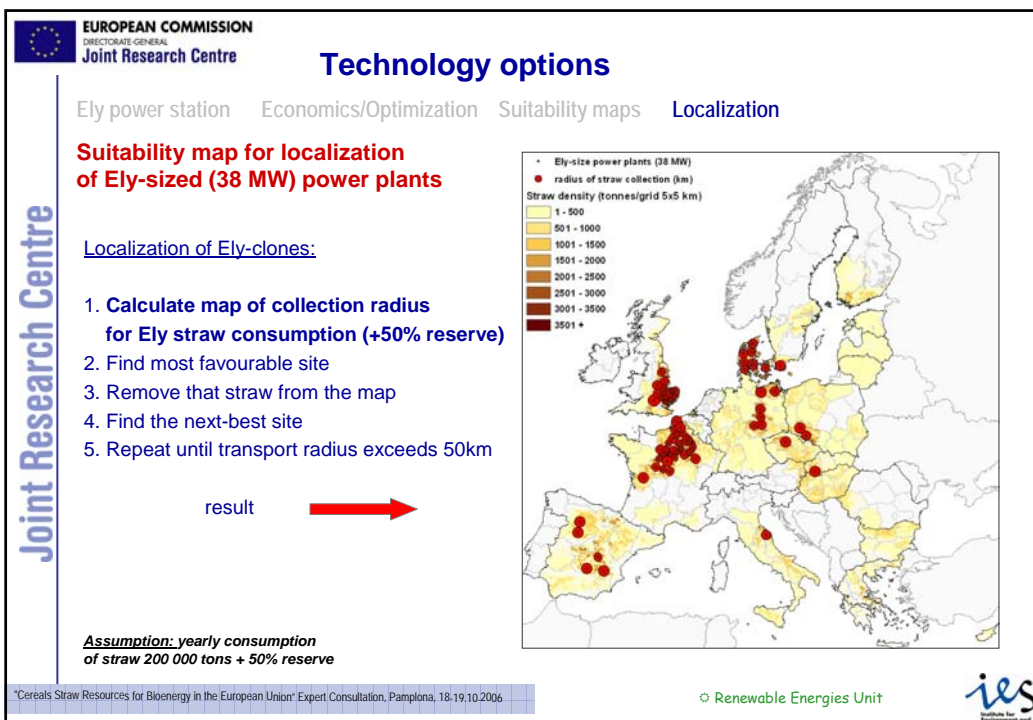
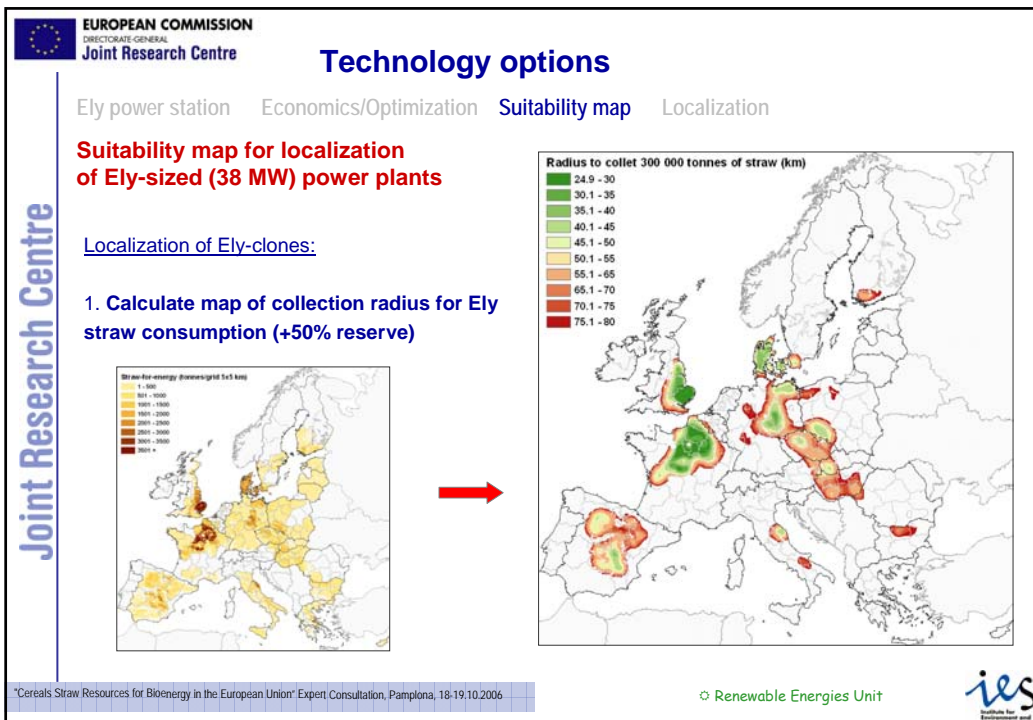
World's biggest straw electricity power plant
(in operation since 2000)

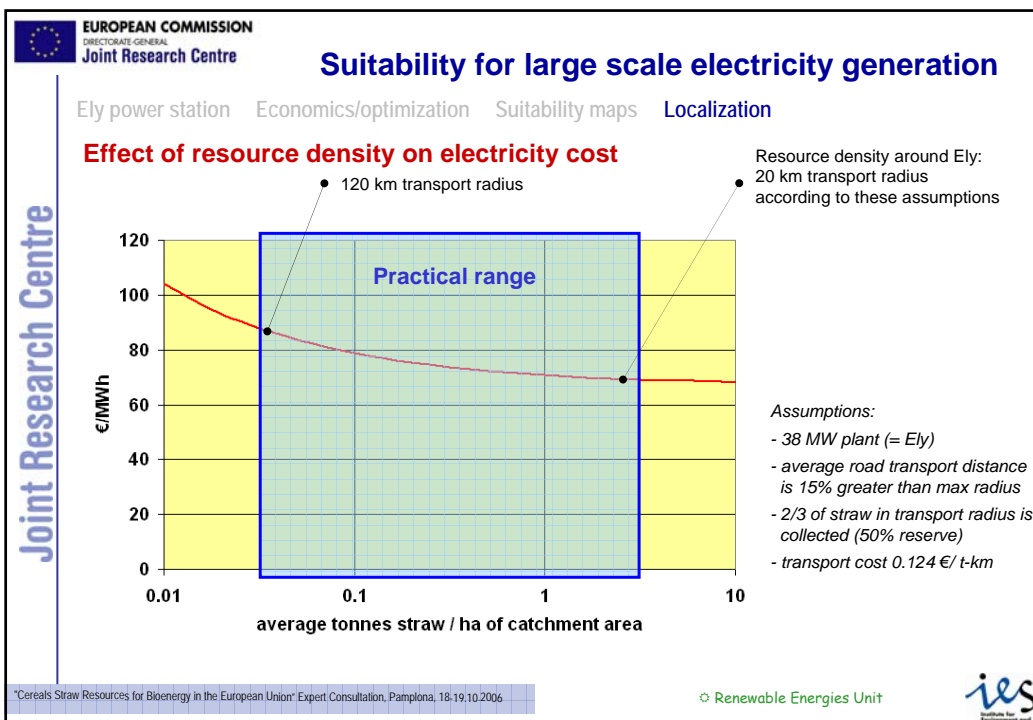
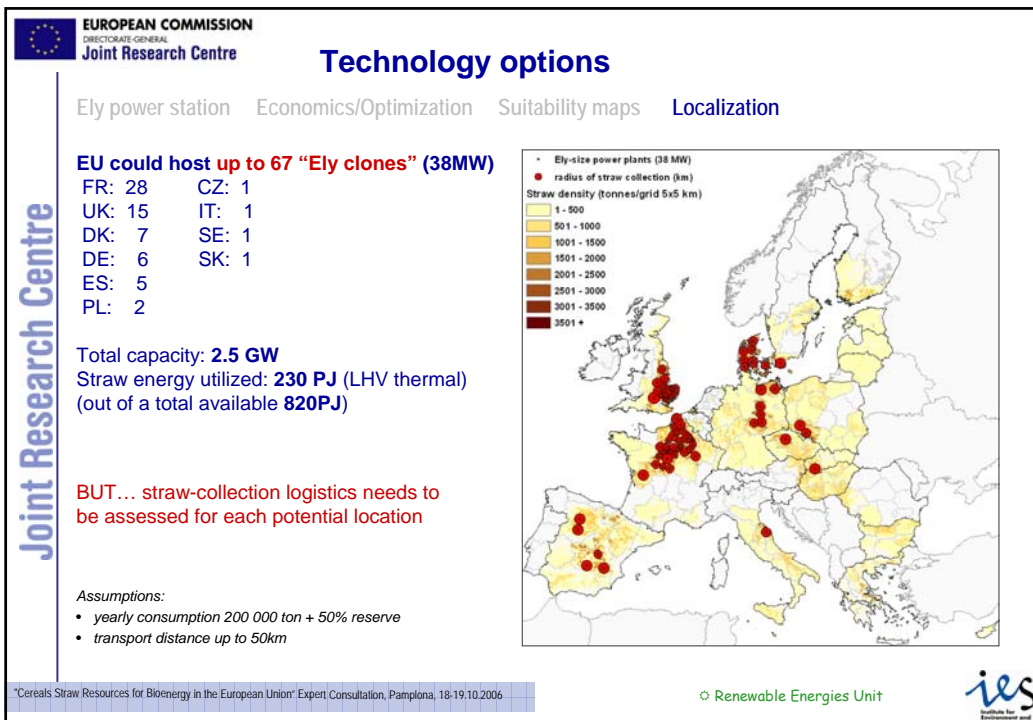
- grate boiler with steam turbine
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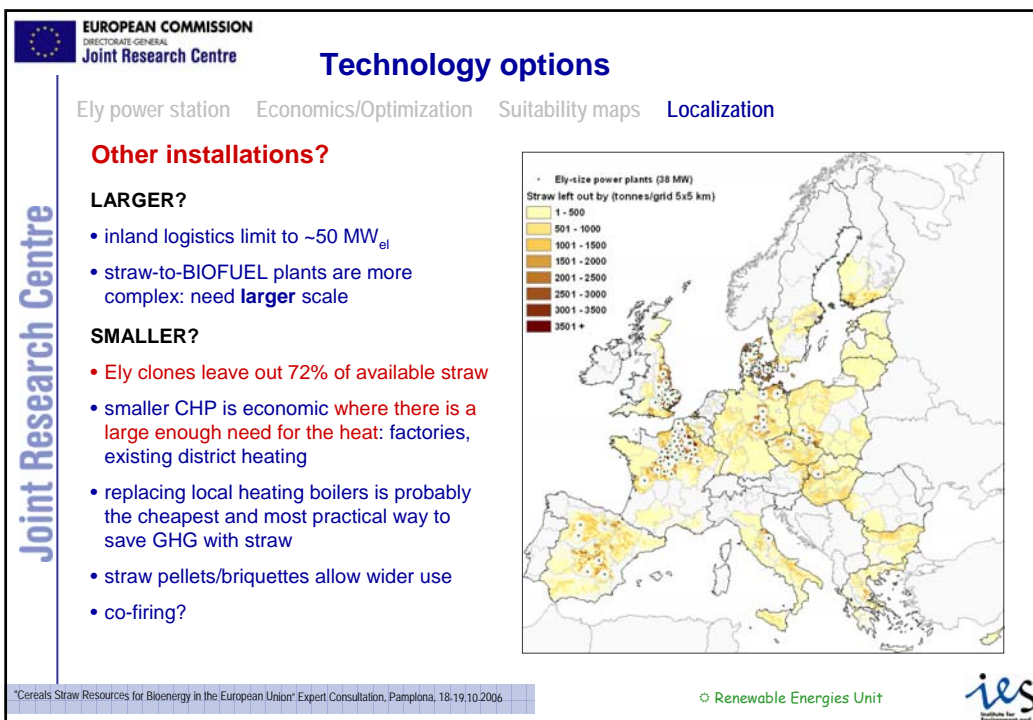
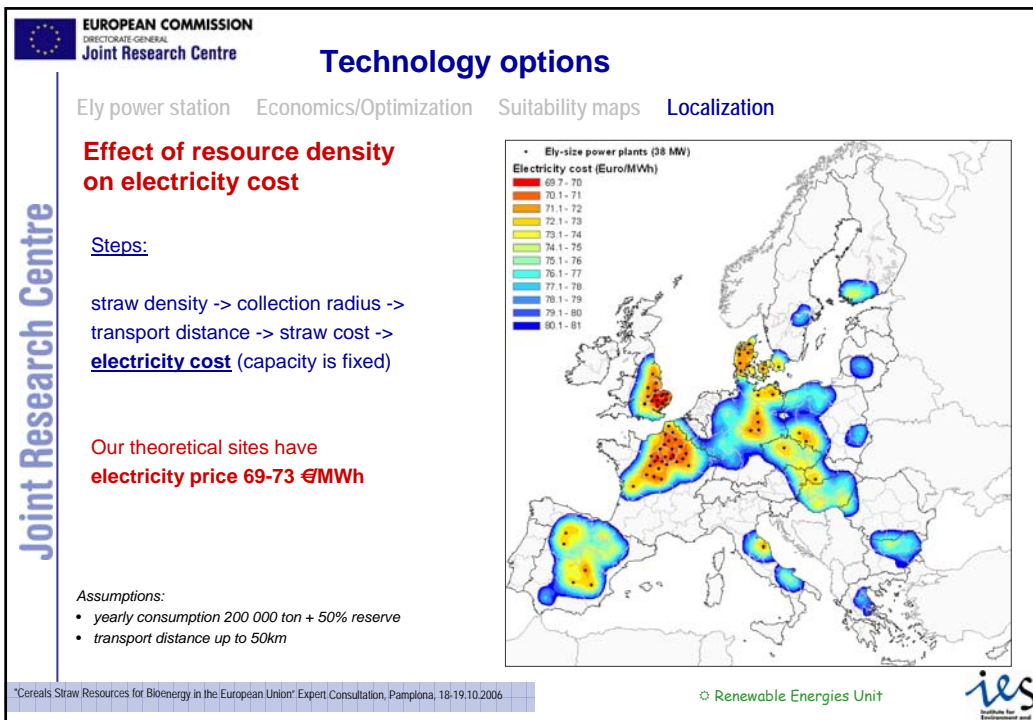
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Conclusions

- harmonized used of data and methodology at the level of EU25+2
- related to the bioenergy technology
- transfer of know-how to other regions


➔

indication of straw energy potential in regions and raising awareness


➔

site-specific studies and decisions are responsibility of national/regional authorities and industry

foto: www.mjansson.com



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The questions to be answered

- local sustainability of straw removal: suitability map
- straw from other resources (rye, rape, maize, rice)
- competitive use – substitution of traditional use
- costs and practical problems (logistics, transportation, storage, social factors, security of supply)
- other use (CHP, heat, pellets, etc.)
- extent of trade between regions

foto: www.mjansson.com



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INTRODUCTION SESSION 1

Cereals straw for bioenergy: **Environmental and agronomic constraints**

*H.P.Piorr, University of Applied Sciences,
Eberswalde, Germany*

**Cereal Straw Resources for Bioenergy in the European Union
Expert Consultation October 18 - 19th 2006, Pamplona**

**- First Session –
Cereal straw for bionenergy: Environmental
and agronomic constraints**

H.-P. Piorr, University of Applied Sciences Eberswalde

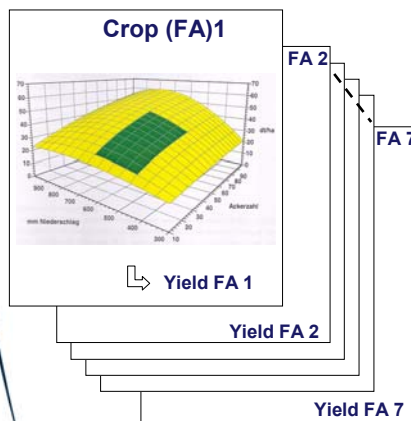
- **GIS mapping at local, regional, national and EU level –
models and statistics for biomass potentials**
- **Straw potentials in Northern Germany**
- **The national dimension – site adapted bioenergy cropping**
- **The European dimension**
- **Farming in East Germany**
- **Environmental constraints – need for setting up
environmental standards for bioenergy cropping**

**GIS mapping at local, regional,
national and EU level –
models and statistics for the
assessment of biomass
potentials**

→ Calculating yields according to site specific agricultural practice.

Energy from Biomass

Model : Crop



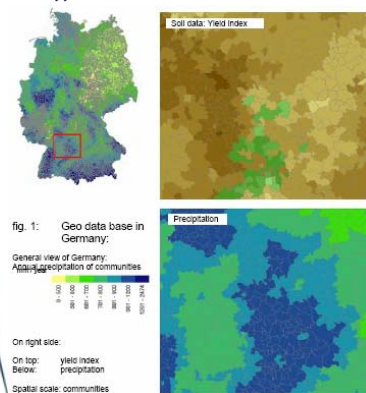
Schematic description of crop rotation algorithms
("Fruchtart" / "FA" = crop, "Ertrag" = yield).

- Modelling of 7 following crops
- Considering the previous crop and the Intercrop
- Results of the crop rotation - Modelling :
 - Yield of crops
 - Yield of dry mass, like straw and leaves from cereals, rape, maize and sugar beets

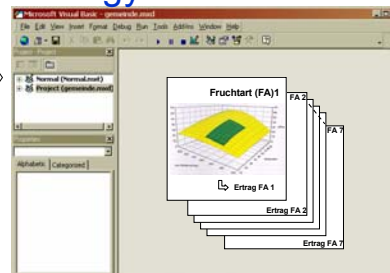
Pierr 2005

→ UASE developed digitized planning maps covering Germany on the level of municipalities. The outcome of this is a realistic basis for planning purposes like biomass production.

GIS-Module „Biomass“:

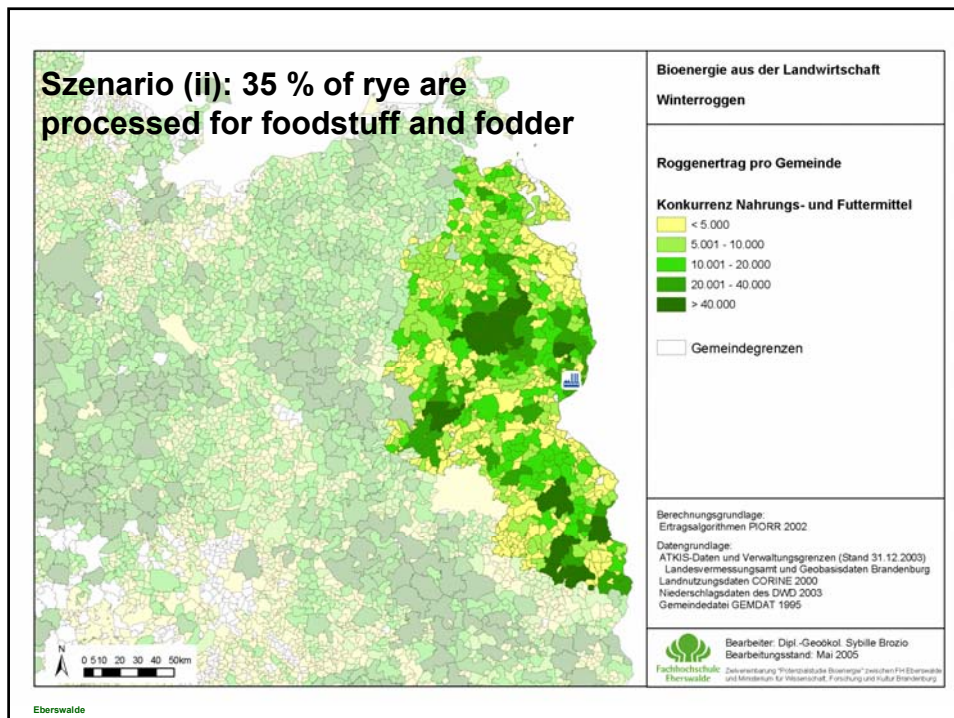
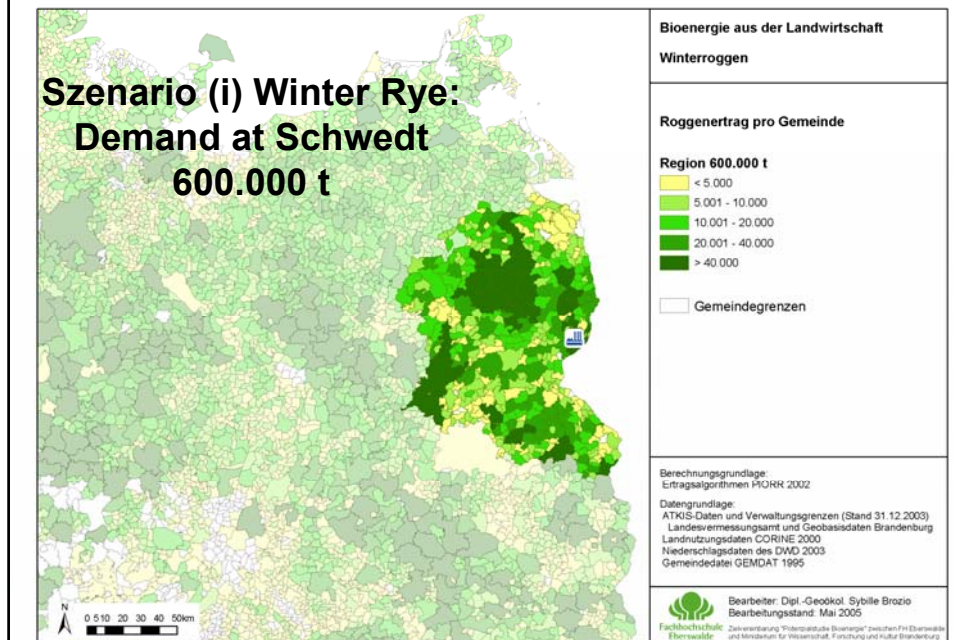


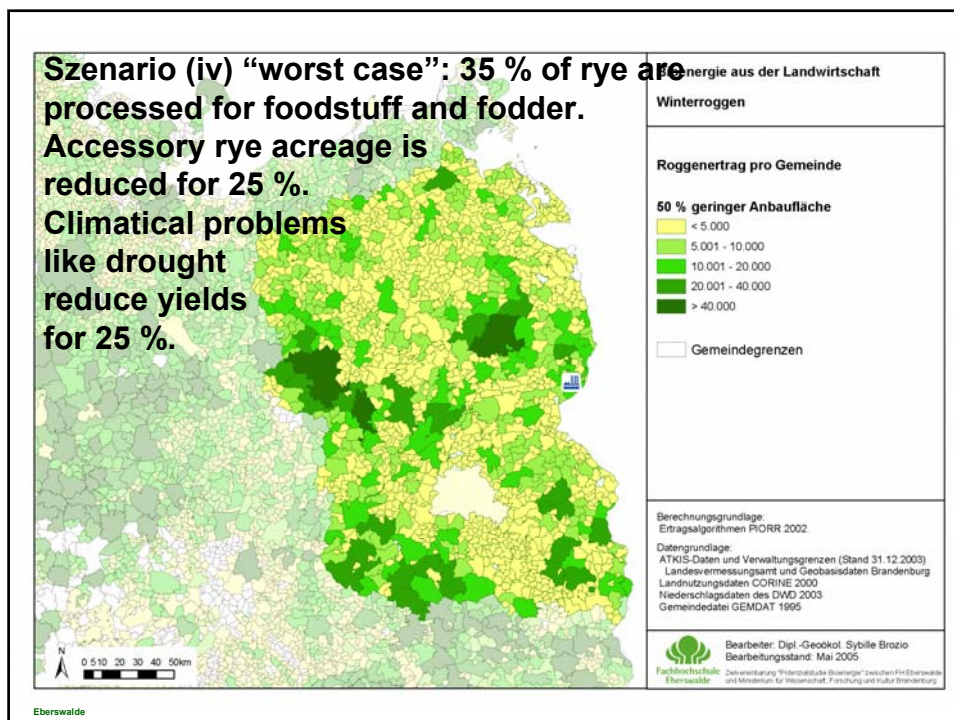
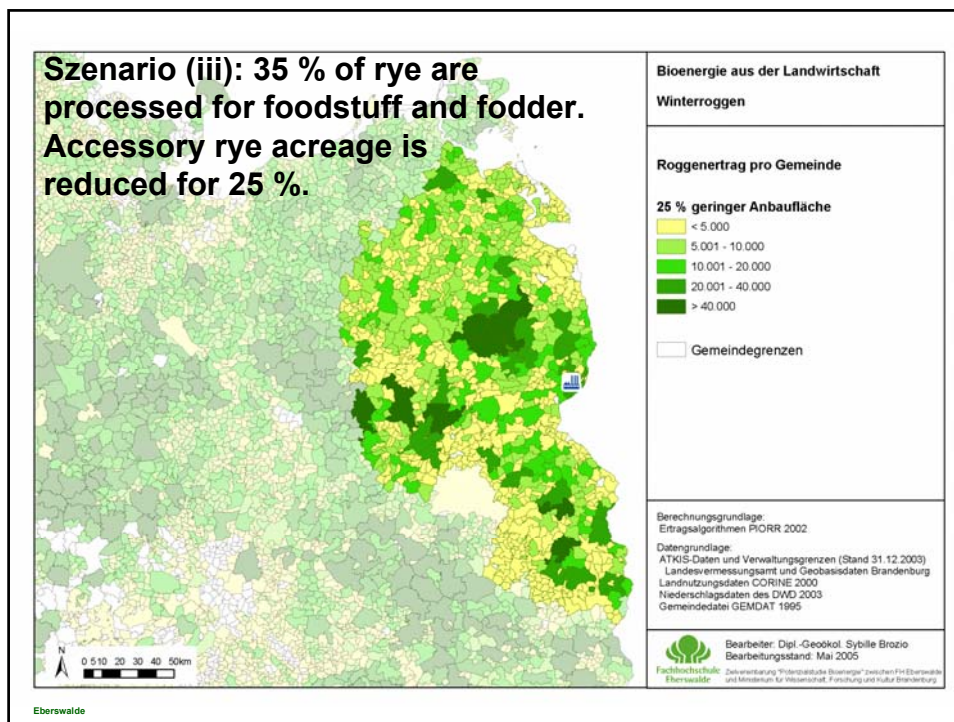
Energy from Biomass



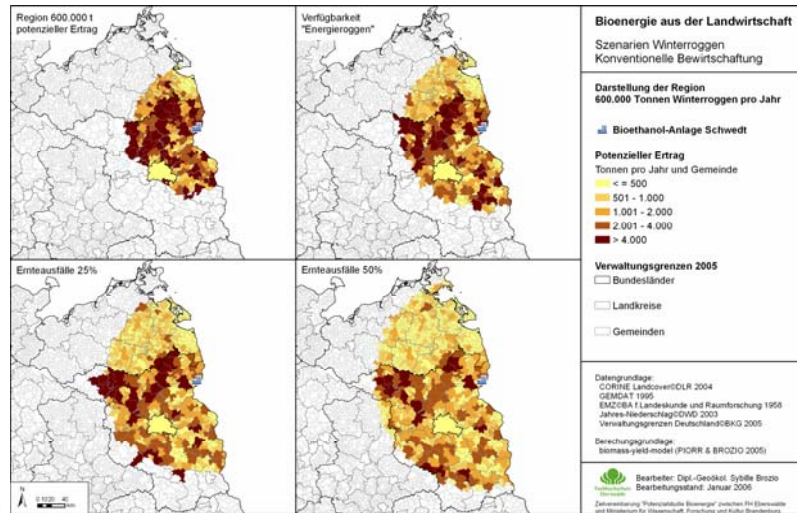
- Allocation of the modell input-parameters to the model level (municipal level)
- Programming of the crop rotation - model

➔ Example Schwedt: Demand for 600.000 t of Rye for Bio-Ethanol.





Results for Planning of Infrastructure



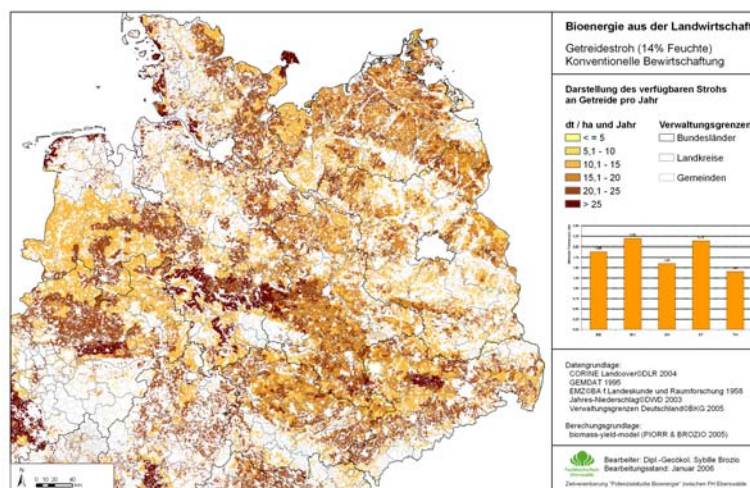
Straw potentials in Northern Germany

Acreage of cereals (ha) in Lower Saxony and the New Bundesländer according to Corine Land Cover map, modelled total straw amount (t) and available straw amount (t)

	Acreage [ha]	Total Straw amount [t/year 86% dry matter]	Available Straw amount [t/year, 86% dry matter]
Niedersachsen	2.115.505	7.715.160	3.857.580
Brandenburg	1.233.987	3.777.100	1.888.550
Mecklenburg-Vorpommern	1.255.316	4.402.940	2.201.470
Sachsen	905.701	3.202.640	1.601.320
Sachsen-Anhalt	1.201.343	4.275.960	2.137.980
Thüringen	794.766	2.822.820	1.411.410

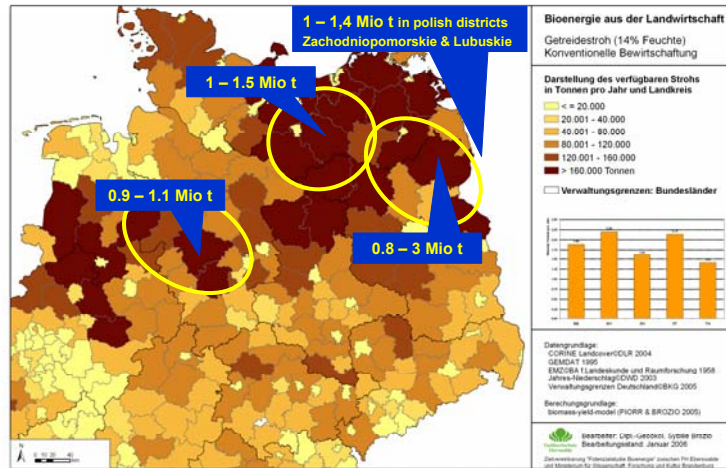
Source: Own calculation on the basis of agricultural statistic

Arable land in Northern Germany and available straw amount (dt/ha*a).



Source: Small scale modelling (Piorr & Brozio 2006)

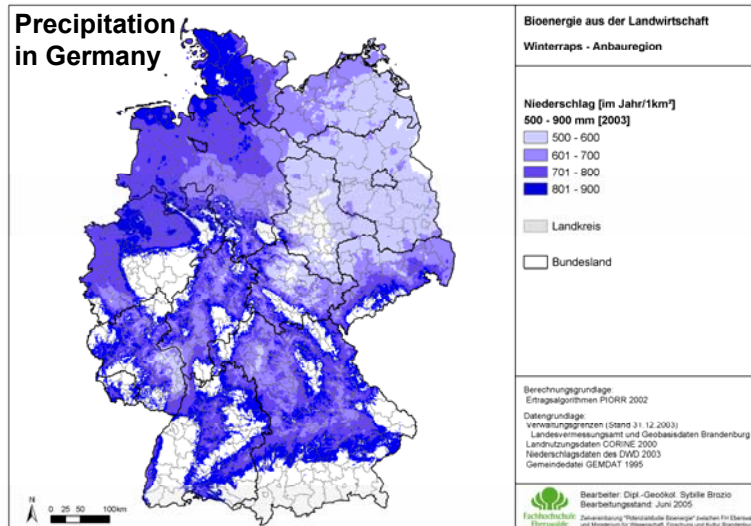
Calculated available straw amounts (t/a) on the level of rural districts and possible production centers (Source: GIS-Maps by UASE model. Piorr & Brozio 2006).



Source: Small scale modelling (Piorr & Brozio 2006)

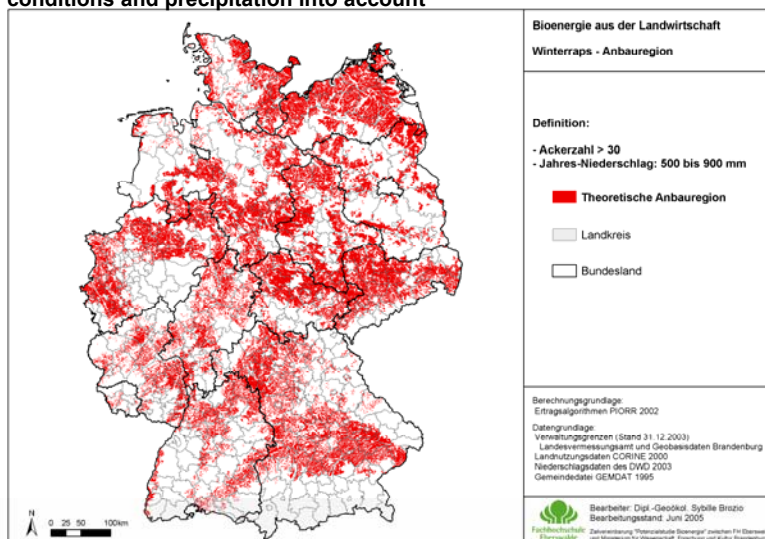
Sustainability of cropping systems and contribution of agriculture to reduction of greenhouse gas emissions

- Calculation of crop yields in Germany: On the level of municipalities, for all crops, differentiated for grain, tubers, beets and by-products like straw.

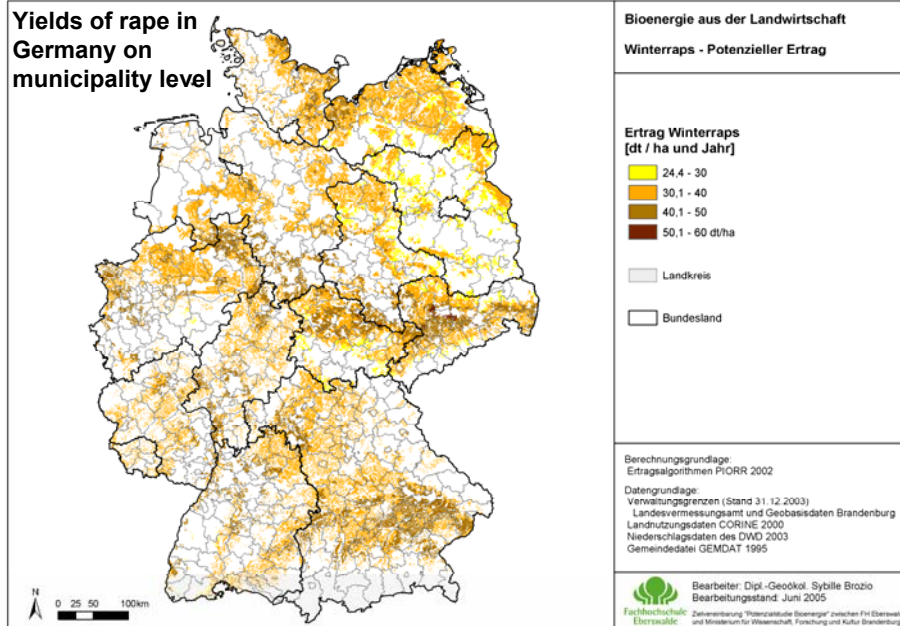


- Selection of sites according to demands of crop concerning growing conditions are considered.

Sites for rape cropping in Germany taking soil conditions and precipitation into account



→ Digitized data on municipality level facilitate the calculation of crop data.



The European Dimension

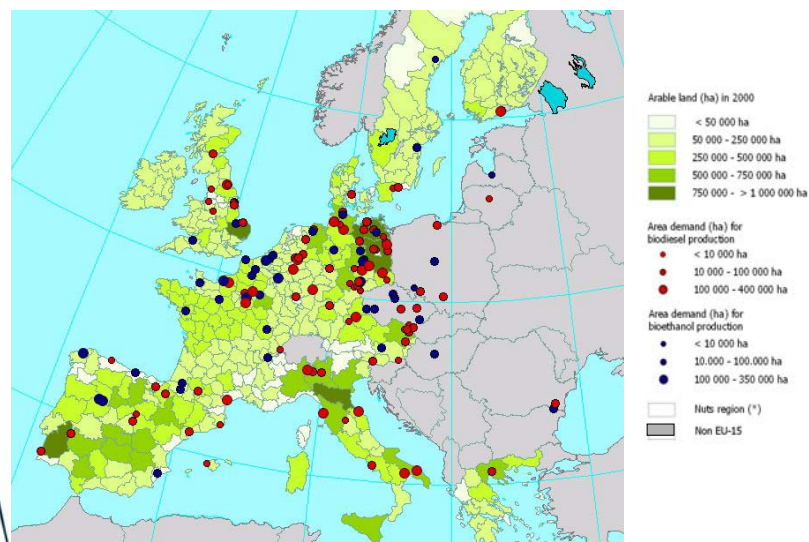
EU goals for biofuels

Demand for biofuels and acreage for energy crops According to the EU Biomass Action Plan COM(2005)628

	2005	2010
Goal for biofuel	2 %	5.75 %
Diesel fuel consumption	158.6 Mio t	165.0 Mio t
Biodiesel demand	3.7 Mio t	11.0 Mio t
Assessed acreage for rape	2.6 Mio ha	7.9 Mio ha
Benzine consumption	124.8 Mio t	113.6 Mio t
Bioethanol demand	3.7 Mio t	9.7 Mio t
Assessed acreage for cereal cropping	1.9 Mio ha	4,8 Mio ha
Total acreage for biofuel (EU₂₅)	4.5 Mio ha	12.7 Mio ha

Source: Bockey (2005)

Production sites for biofuels in and arable land in EU₁₅



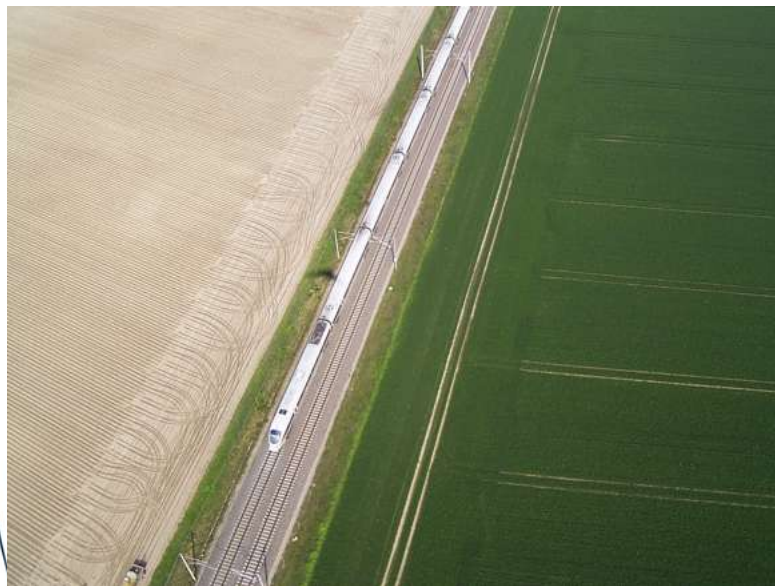
Mid-term capacities for biofuels in EU (operating constructions, plants under construction and planned constructions)

Country	Capacity Biodiesel (t)	Capacity Bioethanol (m³)	Country	Capacity Biodiesel (t)	Capacity Bioethanol (m³)
Belgien		570.000	Niederlande	30.000	160.000
Bulgarien		30.000	Österreich	344.500	200.000
Dänemark	100.000		Polen	260.000	85.000
Deutschland	3.094.000	1.210.000	Portugal	150.000	
Finnland	170.000	100.000	Rumänien	100.000	
Frankreich	941.000	1.716.000	Schweden	48.000	63.000
Griechenland	30.000		Schweiz	2.000	
Großbritannien	577.200	155.000	Slowakei		
Italien	1.031.400		Spanien	321.000	701.000
Lettland		8.000	Tschechien	65.000	200.000
Litauen	10.000		Ungarn		63.000

	Capacity Biodiesel (t)	Capacity Bioethanol (m³)
Total	7.274.100	5.261.000
EU-goal	11.000.000	9.700.000

Farming in East Germany

Huge fields, precise farming



Huge fields, precise farming



Technological capacities, precise harvesting



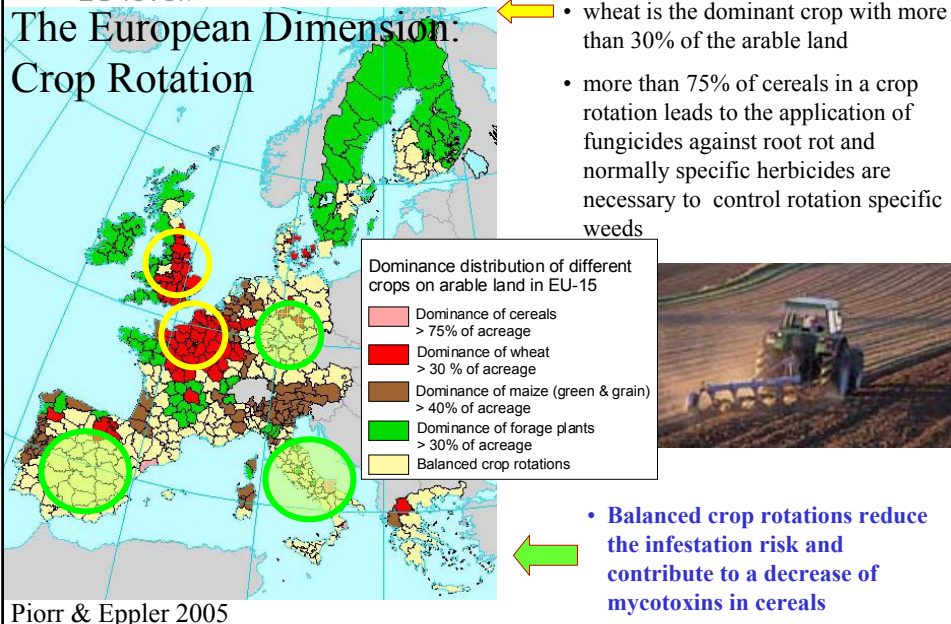
Typical for the Uckermark ...



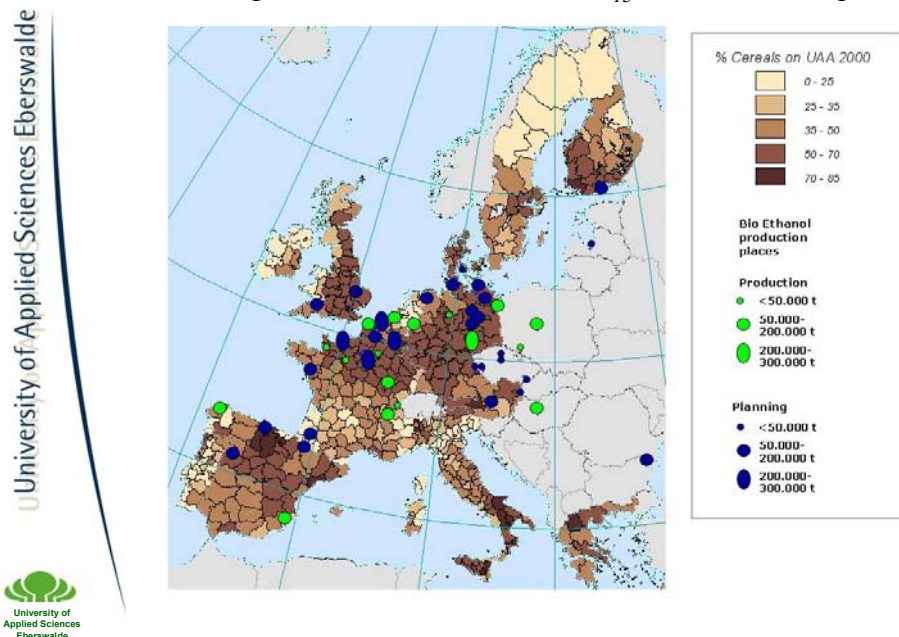
**Environmental constraints –
need for setting up
environmental standards for
bioenergy cropping**

→ The European dimension of biomass cropping for renewable energy. The working team at the UASE is experienced on the EU level.

The European Dimension: Crop Rotation

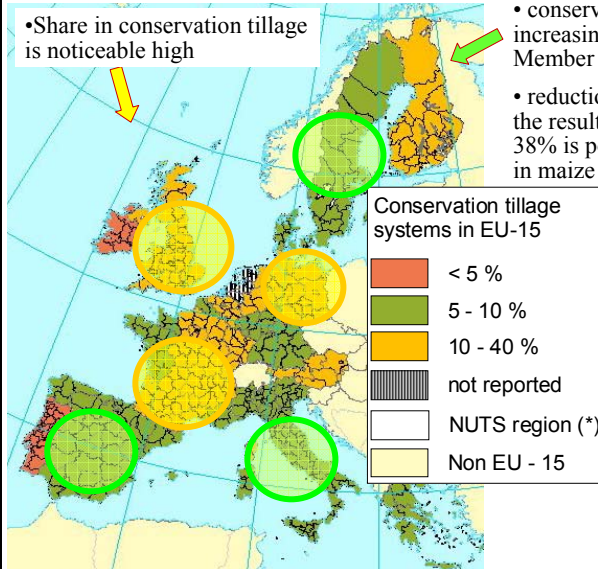


Percentage of cereals on UAA in EU₁₅ and bioethanol plants



Tillage Systems

• Share in conservation tillage is noticeable high



• conservation tillage methods are increasingly being adopted in all the EU-15 Member States

• reduction of the nitrogen concentration & the resulting nitrate leaching from 100% to 38% is possible with undersowing of grass in maize crops

Monitoring of the spreading of innovative cultivation methods is a valuable tool to support decision-makers on the national and regional level to accompany this development with adequate policies.



Threats

- Intensification of farming practices → increase in pesticide and mineral fertilizer applications → higher yields
- decrease in awareness of nutritional risks by pesticide pollution because no nutrition and fodder quality criteria are considered → less control → increased environmental risks
- concentration on high yielding biomass crops → poor crop rotations (monocultures?) → loss of soil fertility → loss of biodiversity → loss of quality of cultural landscapes
- e.g. increase of maize growing in EU
 - soil cover → soil erosion?
 - nutrient balance? → drinking water pollution
 - monocultures? → biodiversity? → weed & pest problems? → herbicide & insecticide application?
 - GMO-maize?

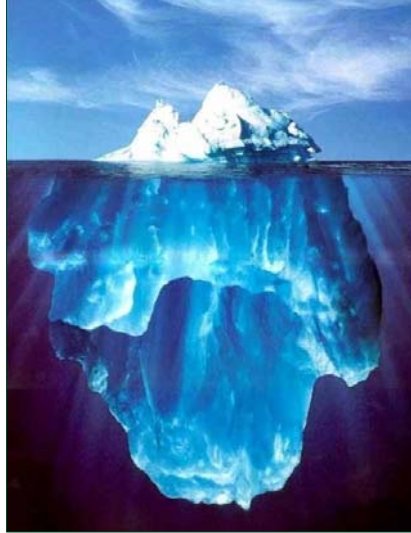
Agricultural bioenergy: minimise environmental pressure by growing the right crops, at the right site within the right cropping system

1. Every bioenergy crop has a specific env. performance & every region requires specific env. considerations
 2. Grow bioenergy crops with low environmental pressure
 3. Introduce a mix of bioenergy crops (maintain crop and landscape diversity)
- erosion
 - soil compaction
 - soil fertility (soil organic matter)
 - nutrient inputs ground & surface water
 - pesticide pollution of soils and water
 - water abstraction
 - biodiversity

Recommendations for next working steps to create a monitoring system to accompany developing Bioenergy Cropping Systems

- **Further evaluation which kind of monitoring system is needed in the very beginning of land use changes by introduction of bioenergy cropping systems**
- **Elaboration of indicators**
- **Analysis of the status quo of bioenergy cropping regions in EU**
- **Ranking of accompanying measures already in the beginning of land use changes**

A lot of questions remain ...



Thank you very much for your attention!

INTRODUCTION SESSION 1


Cereals straw for bioenergy: **Environmental and agronomic constraints**

D.Powlson, Rothamsted Research, United Kingdom



Straw use - energy or soil quality?

David Powlson
Rothamsted Research, UK



Good reasons for using cereal
straw as energy source ...

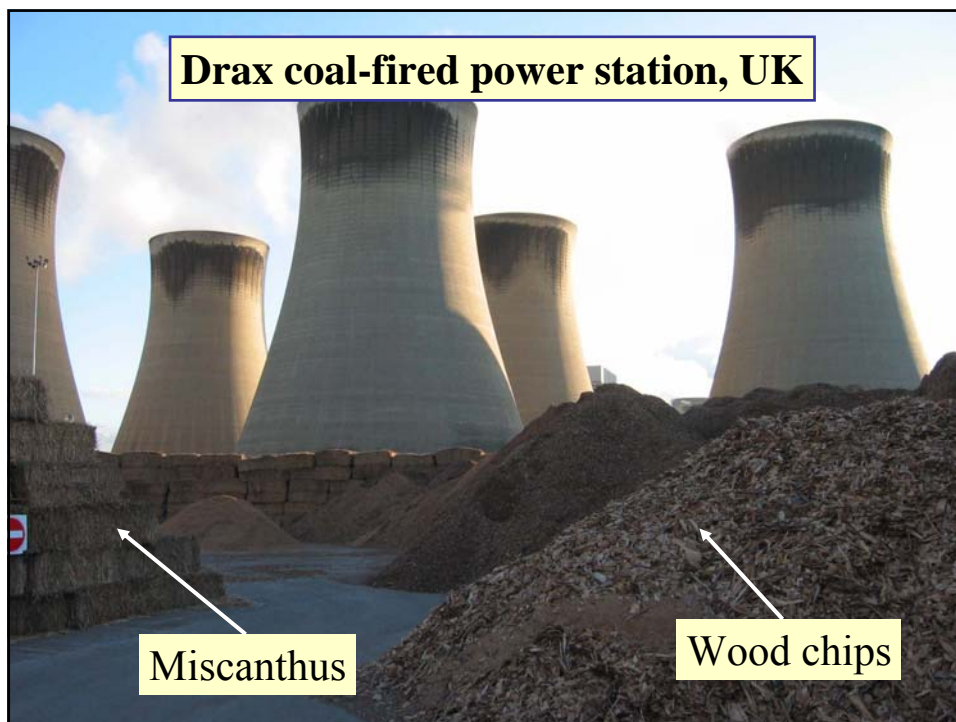
Climate change

“The greatest long-term challenge we face”

- *Tony Blair, UK Prime Minister*

“A greater threat than terrorism”

- *David King, UK Government Chief
Scientific Adviser*



How much UK electricity possible from biomass?

	Scenario details	UK electricity provided, %	
1	80% of current set-aside used for biomass crops	2.7	
2	Use 50% of wood and forestry wastes	} <div>extra biomass</div>	1.6
3	Use 50% of wheat straw		3.7
4	50% current sugar beet area converted to biomass	} <div>extra land</div>	0.5
5	10% of current grassland converted to biomass crops		3.7
	Total all scenarios	12.2	

Powlson, D.S., Riche, A.B. & Shield, I. (2005)
Annals of Applied Biology 146, 193-201

Land use question:
 biomass or
 liquid transport fuels?

Straw -

one of very few options for maintaining soil organic matter (SOM)

- Straw (crop residues)
- Animal manure
- Sewage sludge
- Other organic wastes (e.g., food industry)

Soil organic matter (SOM)



- Influences virtually all soil properties
eg, physical structure, ease of cultivation, ease of root growth, erosion, nutrients, biodiversity (“soil quality”)
- Generally, more is better !
- Additional environmental benefit
locking up (sequestering) C from atmosphere

But not so simple.....!

- **TOTAL** soil organic matter content changes *slowly* in response to straw or other organic additions (years – decades).
- But individual **FRACTIONS** and soil **FUNCTIONS** associated with OM change *faster and proportionately more* than total.

UK Defra project

Objectives included:

- Record farmer's assessment of management benefits from increased SOM (often resulting from straw incorporation)
 - interviewed 110 farmers.
- Estimate financial of value on SOM based on farmer's estimates of management benefits.



Farmer measurements/observations on SOM impacts

Some evidence that farmers could detect changes caused by increased SOM sooner than by traditional “scientific” measurements

Main benefits:

- Cultivation, soil structure, crop establishment, drought resistance, earthworms, less fertilizer

Some negatives:

- Diseases

What determines SOM economic value?

Most important factors:

- Soil type
- Value of crops benefiting from SOM
- Costs of animal manure application
- Price of straw if sold (animal bedding, energy)

Net value of SOM management : €8-80/ha/yr

Considerable assumptions and uncertainties !

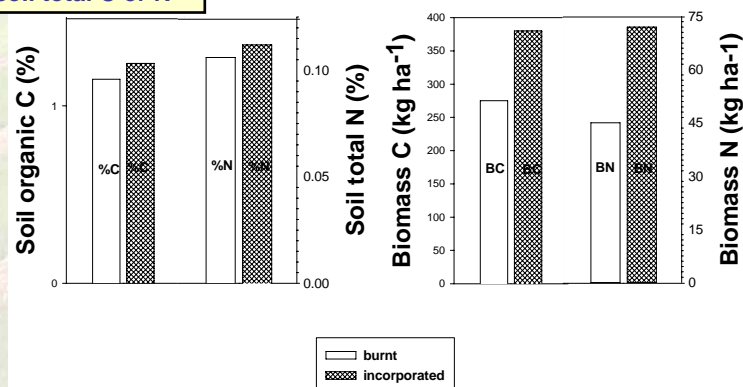
- Highly dependant on nature of enterprise
- Intangibles (e.g. timeliness, flexibility) may be more significant

http://www.defra.gov.uk/science/Project_Data/DocumentLibrary/SP0310/SP03102471_FRP.doc

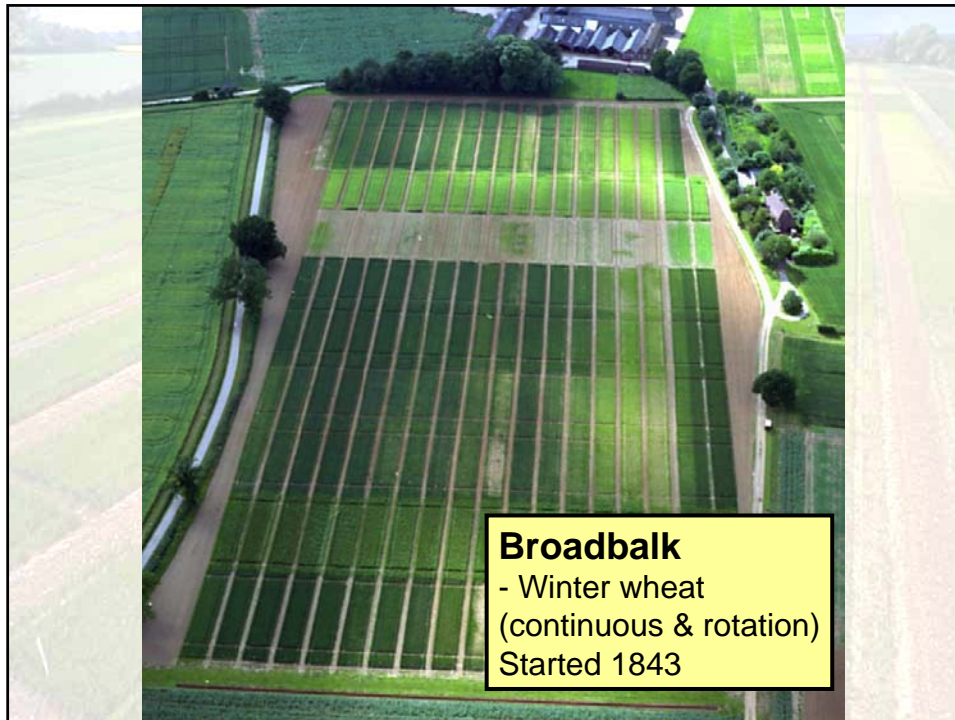
Straw incorporation experiment, Denmark (18 years)

No measurable effect
on soil total C or N

40% increase in microbial biomass



Powlson *et al* (1987) *Soil Biology & Biochemistry* **18**, 159-164



“Labile C” – easily oxidisable – about 10% of total C (microbial biomass + metabolites)

- Increased by straw incorporation and N fertilizer application (larger yields, larger residue returns)
- “Labile C” – correlated with:
 - Increased aggregate stability
 - Increased water infiltration rate

Blair, Faulkner, Till, Poulton.

Soil & Tillage Research **91**, 30-38 (2006)

Rothamsted, Broadbalk Experiment

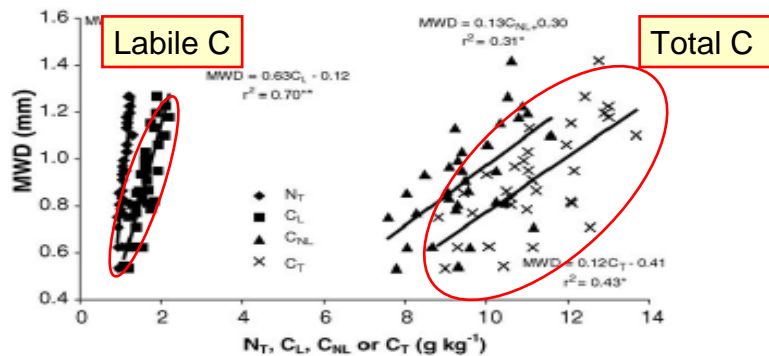


Fig. 2. Linear relationships of total N (N_T), labile C (C_L), non-labile C (C_{NL}) and total organic C (C_T) with mean weight diameter (MWD) for the Broadbalk Wheat Experiment for the low C treatments. (** $P < 0.01$; * $P < 0.05$.)

Aggregate stability related to "labile C"
 - increased by straw and N fertilizer

Blair, Faulkner, Till, Poulton. *Soil & Tillage Research* **91**, 30-38 (2006)

Rothamsted, Broadbalk Experiment

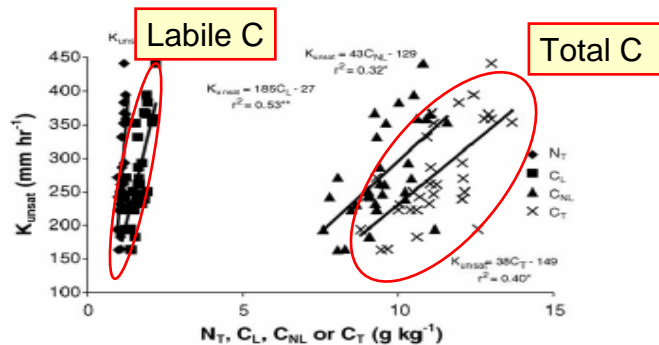


Fig. 3. Linear relationships between unsaturated hydraulic conductivity (K_{unsat}) (10 mm) and total N (N_T), labile C (C_L), non-labile C (C_{NL}) and total organic C (C_T) for the Broadbalk Wheat Experiment for the low C treatments. (** $P < 0.01$; * $P < 0.05$.)

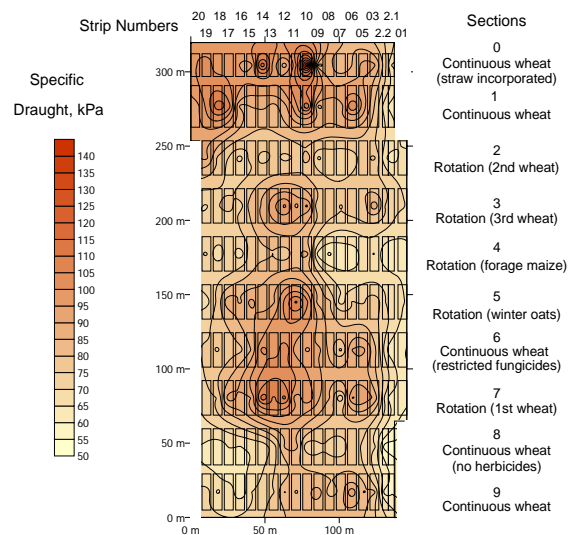
Water infiltration rate related to "labile C"
 - increased by straw and N fertilizer

Blair, Faulkner, Till, Poulton. *Soil & Tillage Research* **91**, 30-38 (2006)

Plough draught

- Small increases in SOM led to decrease in energy required for cultivation
- SOM favoured by increased crop residues (N fertilizer and straw)

Watts, Clark, Poulton, Powlson, Whitmore.
Soil Use and Management (2006,in press)



Watts, Clark, Poulton, Powlson, Whitmore. *Soil Use and Management* (2006,in press)

Potential for soil erosion – southern Spain.

(Rotation: wheat – spring crop); long periods of bare soil.

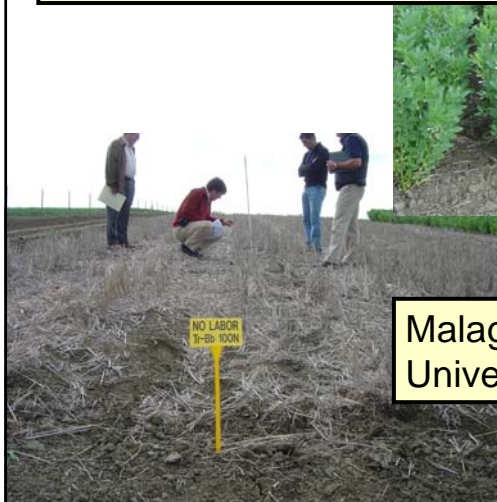
- Soil sustainability
- Water quality – phosphate, sediments

Climate change impacts.

- Bare soil exposed to increasingly intense winter rainfall.
- More spring crops under climate change?

Soil erosion decreased by:

- Minimum tillage
- Straw on soil surface

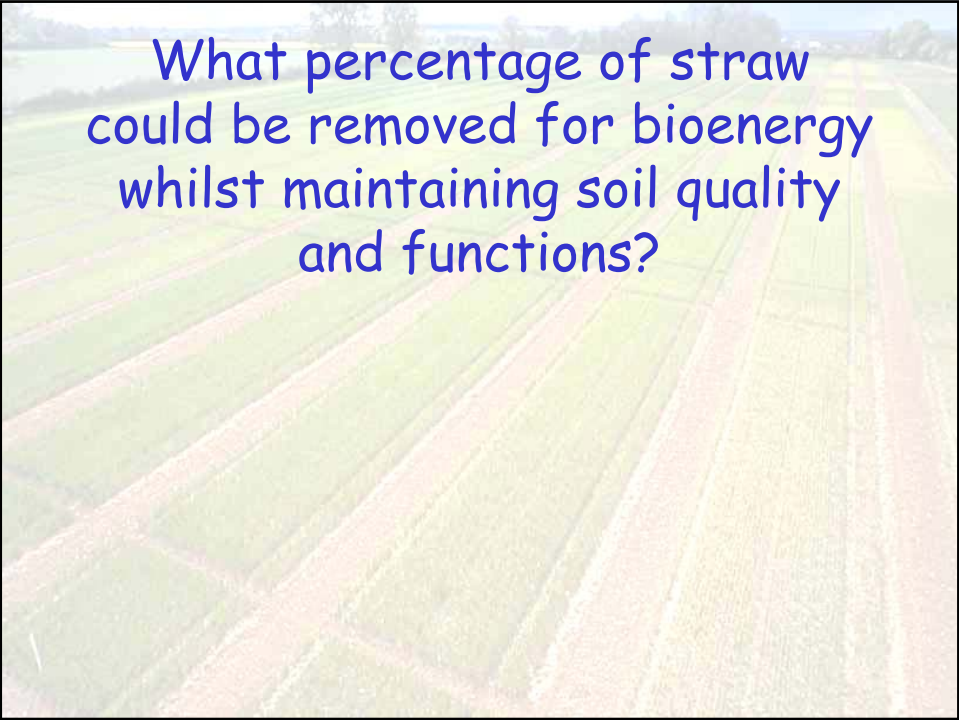


Malagon long-term experiment,
University of Cordoba.



Other benefits from straw

- Source of organic N (very slowly available)
- Source of K
- Immobilisation of N – would expect some decrease in nitrate leaching – but very limited direct evidence of significant effect



What percentage of straw
could be removed for bioenergy
whilst maintaining soil quality
and functions?

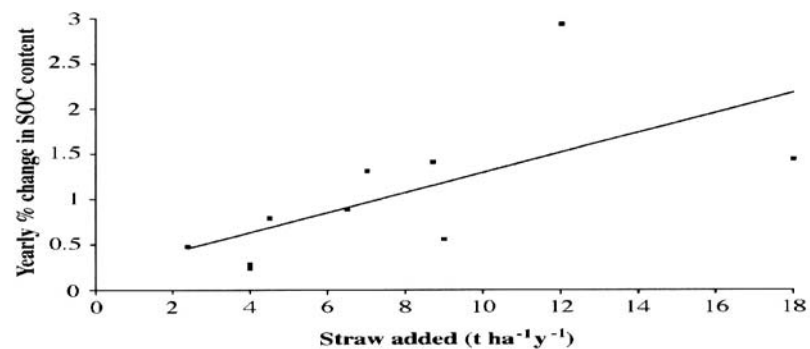
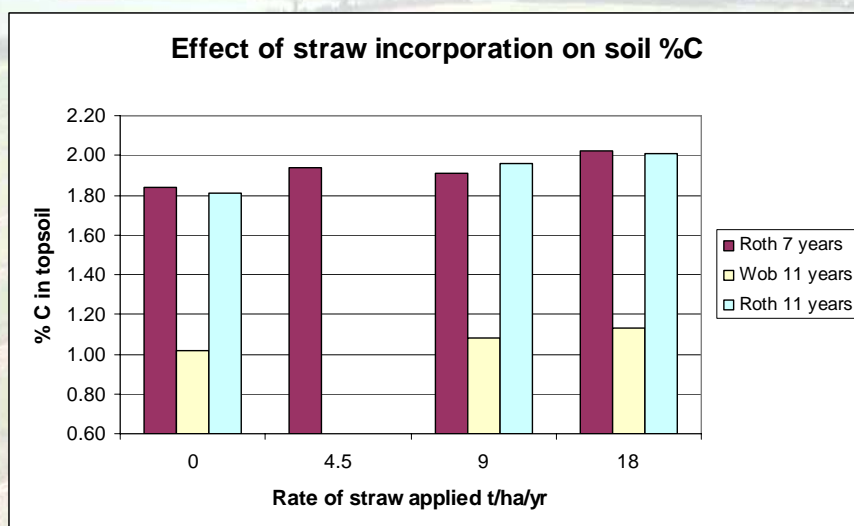
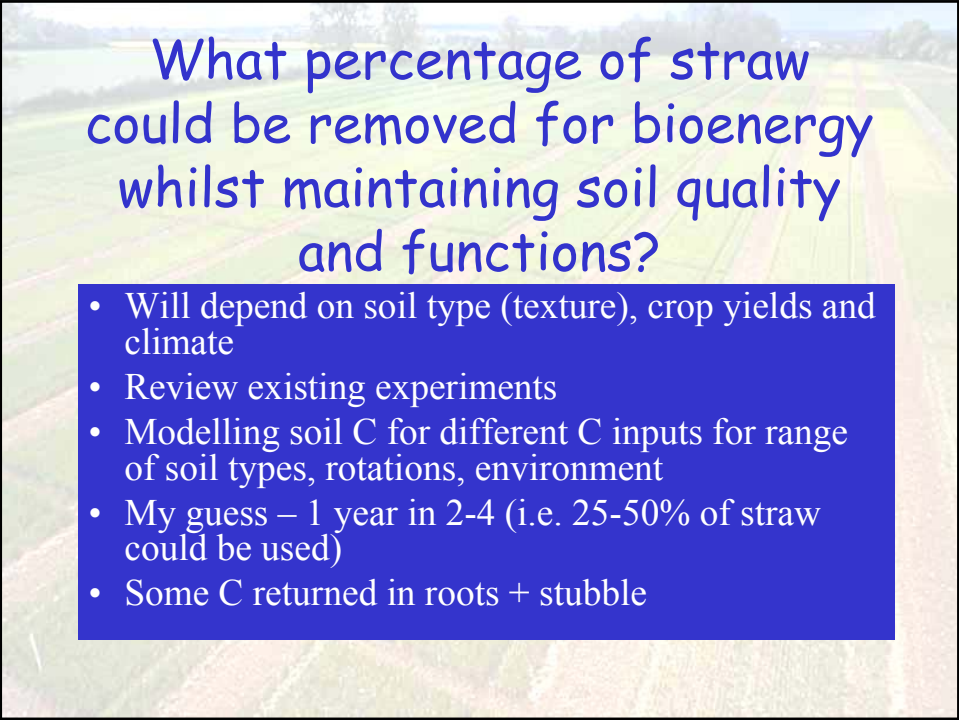


Fig. 3 yearly percentage change in SOC content (difference between straw incorporation and no straw incorporation) with increasing yearly additions of cereal straw. ■ = Plotted points (from Table 7), — = Linear regression trend line following $y = 0.1115x + 0.192$.

Smith, Powelson, Glendining, Smith, Global Change Biology 3, 67-79 (1997)



M.J. Glendining (unpublished)



What percentage of straw could be removed for bioenergy whilst maintaining soil quality and functions?

- Will depend on soil type (texture), crop yields and climate
- Review existing experiments
- Modelling soil C for different C inputs for range of soil types, rotations, environment
- My guess – 1 year in 2-4 (i.e. 25-50% of straw could be used)
- Some C returned in roots + stubble

<http://www.rothamsted.bbsrc.ac.uk/aen/CarbonCycling/>



REPORT SESSION 1

Cereals straw for bioenergy: **Environmental and agronomic constraints**

D.Powlson, Rothamsted Research, United Kingdom

Session 1

Environmental & agronomic constraints

Straw - has value for 'soil quality'

- Straw - one of few management tools for maintaining soil organic matter (SOM) – so *caution about removal!*
- SOM – key determinant of soil functioning ('soil quality') and sustainability of functions. Affects physical, chemical, biological properties
- Practical & financial value to farmer from well-functioning soil – and value to society of well-functioning agro-ecosystems.

- Soil ***physical properties*** (e.g. aggregate stability, ease of tillage, seedling emergence, water infiltration rate) influenced by SOM. Knock-on impacts on agronomy, pesticide use, etc. in addition to crop yield.
- Influenced by “labile”/fresh SOM more than total content.
- Such fractions greatly influenced by organic inputs (from roots, stubble, straw, manure).
- But some C inputs from roots + stubble even if all straw removed.

Key question

How much straw can be removed whilst still maintaining sufficient SOM for good soil functioning?

- Different soil types, environments & cropping systems will differ in sensitivity to C removals
- Determine “sustainable straw removal rate” for different situations.
 - Establish sensitivities
 - May be zero removal in some cases
 - Consider whole rotations
- Can approach with different levels of precision/complexity
 - Local knowledge (advisers, scientists, farmers)
 - Results from field experiments (local or extrapolated).
 - Models, C budgets (e.g. – German system; France, Picardie example – removal 1 year in 3).
 - Modelling – to establish required C inputs.

Straw for surface mulching

- Valuable for controlling soil erosion in some situations – so an additional ‘use’ for straw – may be combined with minimum tillage.
- In contrast – some minimum tillage systems with high crop yields *require* straw removal – so fit well with straw removal for bioenergy

Nutrients - P,K

- P & K removals in straw are significant – represent a decline in soil fertility.
- Replacement with inorganic fertilizers has a cost – financial & environmental (LCA).
- Ideally return ash to soil
 - Practical, environmental & regulatory issues – waste or fertilizer?
 - Physical form

Nutrients - N

- Some return of organic N in straw (about 5 kgN/t straw) – very slowly available.
- Tie-up of N as straw decomposes (immobilisation) – may be beneficial for N losses – small effect?

- Consider (unexpected) implications for crop management practices & cropping systems
 - May be either positive or negative environmentally
 - Income source for farmer
- Potential conflicts – harvesting time/logistics – farmer v. power plant operator?
- Power generation plants using a mix of materials
 - straw *and* biomass crops (e.g. miscanthus, switchgrass, woodchips) may be best option – spread demand for biomass.

INTRODUCTION SESSION 2

Cereals straw for bioenergy and competitive uses

*F.Labalette,
GIE ARVALIS/ONIDOL, France*

*C.Panoutsou,
Imperial College Centre for Energy Policy and
Technology, United Kingdom*

Experts consultation- Pamplona, 18 – 19th October 2006

Cereals straw for bioenergy and competitive uses

Dr Calliope Panoutsou

Imperial College London

Françoise Labalette

ONIDOL (French oilseed crops organization)

and GIE ARVALIS/ONIDOL

*(Group of economical interest for biomass energy
between cereal and oilseed crops organizations)*

Contents

- Aim
- Cereals in EU25: current state
- Key factors for potentials
- Cereals straw:
 - Potential
 - Recent studies (JRC, LOT5 Bioenergy)
 - Restricting factors
- Competitive uses
- Energy aspects
- Straw from other crops
- Challenges
- Conclusions /Recommendations

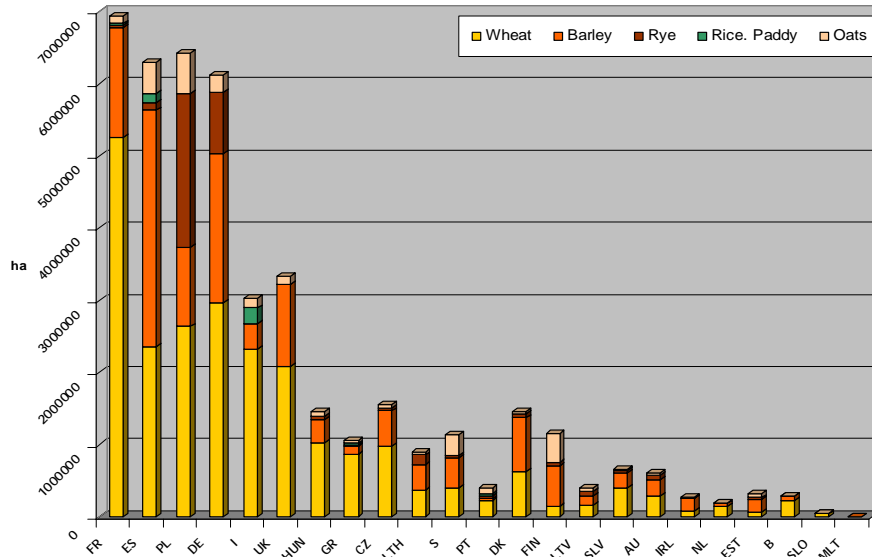
Aim

- State of knowledge, and
- Answers for:
 - Competitive uses & potential for quantified data at local/ regional and national level,
 - Straw resources additional to wheat and barley
 - Data collection on straw use/ potentials?

Current State

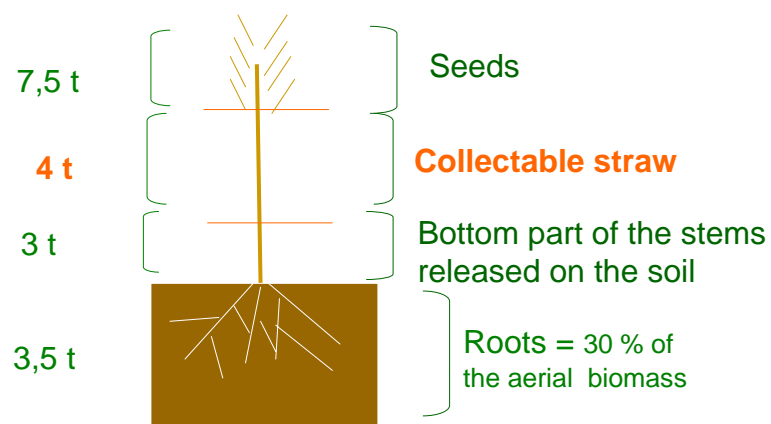
- Crops: Wheat, Barley, Oats, Rye, Rice
- EU 25 cultivated area: 44 million ha
- 38% of arable and permanent crops land in EU25
- 60% of the cereals cultivated area is in FR, ES, DE and PL
- Wheat covers the largest part in most member states

Land Use (FAO, 2004)



Cereals straw potential: Key parameters

Collectable and useable Straw : only 50 to 60 % of the biomass released after seeds harvest



Cereals straw potential: Key parameters

As consequence : when straw is collected,

- we do not extract all the produced organic matter
- We keep more than 50 % of the organic matter in the field

Cereals straw potential: Key parameters

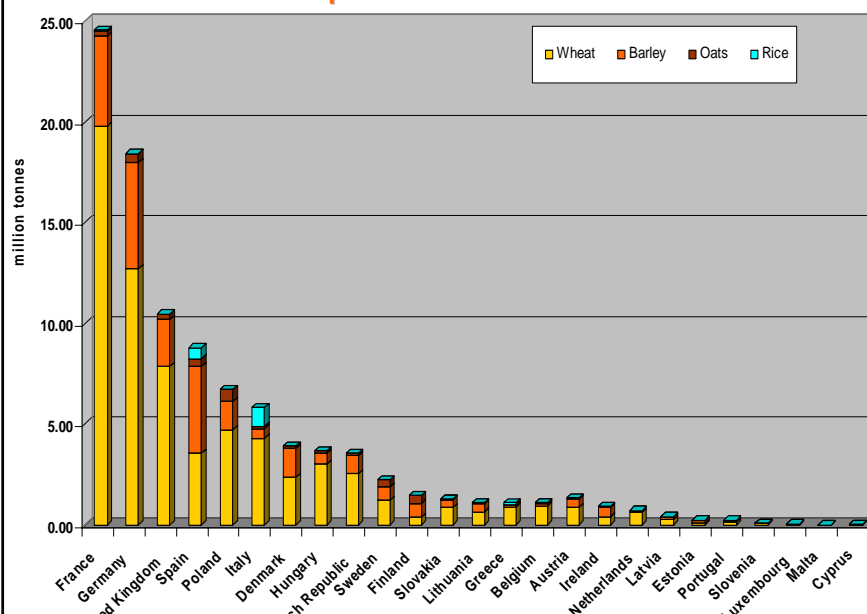
- Diversified yields/ species in different EU regions (3 t/ha- 5.5 t/ha)
- Collection only a few weeks/ year SO high storage requirements
- Field & pressing losses $\leq 20\%$
- Transport & Storage losses $\leq 10\%$
- Demand from competitive markets $\leq 50\%$

Average factors for potentials

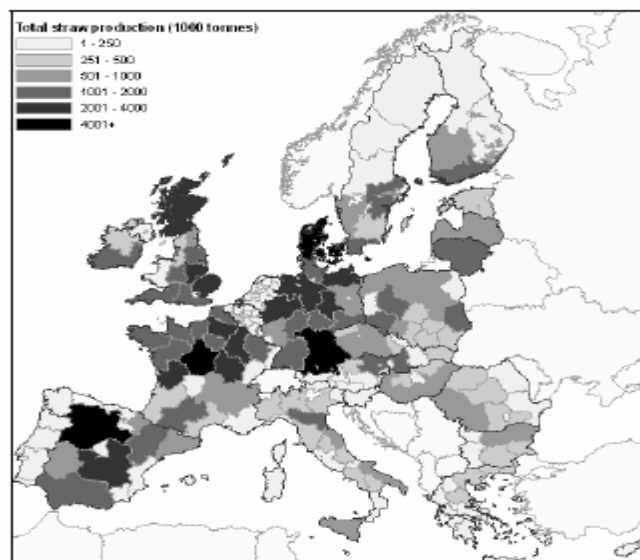
(source: LOT5 Bioenergy)

	Product/ Residue	Technical availability	Moisture Content (%)	Energy content (MJ/ kg)
Wheat	1	0.5	15	17.9
Barley	1.24	0.5	15	17.5
Oats	1.27	0.5	15	17.4
Rice	1	0.6	25	16.7

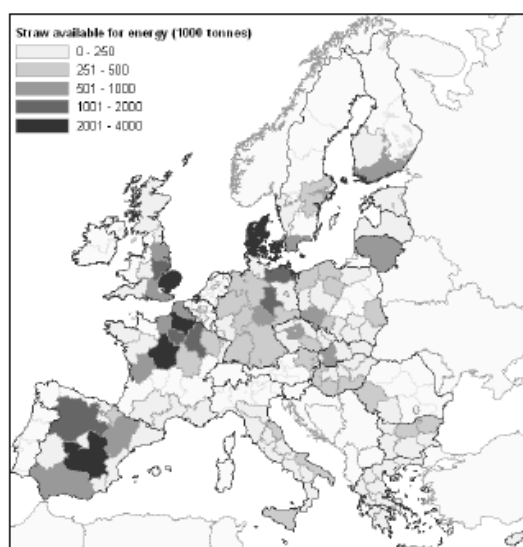
Based on previous slide:
Cereals straw potential: 84 M tonnes



Straw production (1000 tonnes/ region) at NUTS2 level
(2003 harvest, except Spain- 2002, and Bulgaria-
2001). JRC study, based on EUROSTAT data



Net straw surplus (1000 tonnes/ region) at NUTS2
level (2003 harvest, except Spain- 2002, and Bulgaria-
2001). JRC study, based on EUROSTAT data



Restricting factors

- Straw production varies from year to year resulting sometimes in shortages in some years depending on weather conditions
- Straw yield varies among EU regions: central and north are more productive than south
- Modern combine cut stems higher and grind more the straw: so lower collectable production
- Cereal breeding is directed towards production of short stems varieties (to prevent lodging)

TWO MAJOR Competitive uses

(source: ETSU, 1994 + French studies of the GIE)

- Animal bedding and feeding : higher needs : cattle and chickens (ex 1,5 t/y of straw/ cattle unit). For local use or exports
- Soil return : For local use and depending on :
 - Crops rotations
 - Soil type
 - organic matter status
 - External organic inputs (ex sugar industry residues)Few experimental references of straw collection impact on organic matter content (lack of long duration field trials)

Hard discussion on the right rate of straw collection allowing soil fertility conservation

Other Competitive uses

(source: ETSU, 1994 + French studies of the GIE)

- Crop Protection: Used, mainly in northern EU regions where low temperatures exist, for the protection of carrots and other sensitive vegetables (parsnips, etc.) from frost when they are left in the ground during winter. Local use
- Composting (mushrooms): Wheat straw is used to provide a composted medium for the mushroom growing industry. Local use
- Others (paper pulping, panels)
 - Between 30 % and 100 % of the total straw potential unavailable for energy, depending on the local pedo-climatic and market conditions

Socio-economical aspects

- Acceptability of collecting straw at farmer level,
 - work planning : ex: short time between wheat harvest and rapeseed sowing in northern France
 - historical impact of extension services advises on organic matter management
 - personal reluctance for environmental concerns
 - but price level can change the opinion but not always

(source : GIE Arvalis/Onidol , socio-economical study on going in France in the Picardie region)

Energy aspects

Straw as a fuel

- Straw that has been lying in the field (grey straw) and has been exposed to rain has a reduced content of corrosive matter (chlorine and potassium) and is better for the boiler.
- Grey straw has also a higher calorific value than yellow straw.
- So far straw washing has been tried at small plants.

Straw as a fuel

	Unit	Yellow straw	Grey straw	Wood chips	Coal	NG
Moisture	%	10-20	10- 20	40	12	0
Ash	%	4	3	0.6- 1.5	12	0
Carbon	%	42	43	50	59	75
Hydrogen	%	5	5.2	6	3.5	24
Oxygen	%	37	38	43	7.3	0.9
Chloride	%	0.75	0.2	0.02	0.08	-
Nitrogen	%	0.35	0.41	0.3	1	0.9
Sulphur	%	0.16	0.13	0.05	0.8	0
Calorific value	MJ/kg	18.2	18.7	19.4	32	48

Cereals straw supply for energy

- Straw in large scale CHP- DH plants is limited by the availability of the resource (DK, UK 50-100 MWth).
- Currently straw transportation feasible for 50-100 km.
- Straw pellets can be used as a fuel in large boilers, whereas ash and slagging problems make them less suitable for use in small boiler plants.

Cereals straw supply contracts: the case of Denmark

- Trading straw for energy is determined by contracts between individual farmers or associations, including some of the following:
 - Provisions in the event of increase/ decrease in the delivery due to decrease in crop yield.
 - Terms of delivery such as the type of bale, water content, etc.
 - Basic price and the regulation of price in proportion to water content and time of delivery.
 - Provisions concerning the regulation of the basic price.

Straw from other crops

Straw from other crops: Corn

- *Corn* is one of the main agricultural crops, mainly in southern EU countries. Approx 6.5 million ha are being cultivated with corn in EU25 with a grain production of 54 million tons (FAO, 2004).
- *Corn residues*, including mainly stalks and ear cobs, represent also a significant energy potential and they are estimated at 38 million tons based on a 0.7 corn grain/corn residues ratio or an average of 5.5 tons/ha dry field corn residues. Jenkins and Sumner (1986) reported 9 tons/ha field corn residues yield.

Straw from other crops: Corn

- *Experience of corn straw collection in France : 5,5 to 6 t/ha, to be confirmed at large scale*
- *Barriers :*
 - Late harvest and high stalks humidity
 - Low occurrence of dry periods for straw drying on the soil
 - Possibility of winter straw collection but yield decrease

(source : 2006 French study, GIE Arvalis/Onidol)

Straw from other crops: Rapeseed

- Large areas are cultivated with rapeseed. In EU25 a total of 4.2 million ha are being cultivated with rapeseed (FAO, 2004). It is estimated that 15.6 million tons of seeds are produced annually.
- The annual field residue production has been estimated at 21.3 million tons based on a 1.6 seed/residues ratio (Hevin, 1995).

...

But modern harvesting processes lead to increase cutting high and to chop the straw

Question : Is it better to return the rapeseed straw on the soil for durable rotation including wheat straw collection?

Straw from other crops: Sunflower

- Sunflower is grown mainly for oil production for human consumption in certain EU regions (FR, ES, I, PT, DE, HUN, SLO, AU, GR, etc.). In 2005, from 2.2 million ha cultivated (FAO, 2004) the seed production was equal to 4.2 million tons.

Dry field residues are estimated at 3 million tons with France accounting for almost one million tons and Hungary and Spain following with 0.86 and 0.56 million tons.

...but feasibility of the straw collecting is not proved...and density of the bales are decreased

Challenges

- Data collection requires correct factors for:
 - Residue/main product ratio
 - Moisture Content
 - Availability factors
- Establish links with EUROSTAT/ FAO to discuss initiating the process of including straw statistics in the their agricultural data.
- Make sure regional differences in yields are captured.
- Optimize harvesting/ collection and logistics issues to match the requirements of the technologies and the end products.

Conclusions/Recommendations

- All biomass residual resources, available at EU25 level should be monitored and recorded at an annual basis with a common methodology.
- Form questionnaires, covering both the agricultural and the energy aspects of straw/residue collection and energy exploitation.
- Make sure environmental aspects are taken into account.
- Evaluate synergies/ antitheses with other straw markets.

References

- GIS-Based assessment of cereal straw energy resource in the EU. R.H. Edwards, M. Šúri, T. A. Huld, and J. F. Dallemand
- www.videncenter.dk. Straw as an energy resource
- FAO, 2004
- EUROSTAT, 2005
- LOT5 Bioenergy project: Bioenergy's role in the European Union
- www.fairbiotrade.org
- Reports of the GIE Arvalis/Onidol

REPORT SESSION 2

Cereals straw for bioenergy and competitive uses

*D.Schieder,
Technical University of Munich, Germany*

Expert Consultation

„Cereals Straw Resources for Bioenergy in the European Union”

Report Session 2

Cereals Straw for Bioenergy and Competitive Use

Agenda

- Introduction: Presentation of Dr. Labalette
- Discussion

Topics

1. Production of straw in the EU25 - current situation
2. Restricting factors on the availability of straw
3. Technological aspects of straw combustion
4. Competition and market organisation
5. Summary

Expert Consultation „Cereals Straw Resources for Bioenergy ...”, Pamplona, 18.-19.10.2006, Report Session 2, Dr. Doris Schieder

1. Production of Straw in EU25 – Current Situation

Production data of cereals straw

- Cereal crops: Wheat, Barley, Oats, Rye, Rice
- Production in 2005: 44 Mio. ha = 38% of arable land in the EU25
- Main producers: France > Spain > Poland, Germany
- Productivity: 3 – 5,5 Mg/ha depending on local conditions (soil, climate)

Straw from other crops

- Corn: 6,5 Mio ha corn – approx. 38 Mio Mg/a residue (residues not completely collectable!)
- Rape: 4,2 Mio ha rapeseed - 21 Mio Mg/a straw
- Sunflower: 2,2 Mio ha sunflower (technical feasibility of straw collection uncertain!)

Expert Consultation „Cereals Straw Resources for Bioenergy ...”, Pamplona, 18.-19.10.2006, Report Session 2, Dr. Doris Schieder

1. Production of Straw in EU25 – Current Situation

Aspects of straw harvesting

- **Roots and stems > 50% of total crop biomass**
 - ➔ with respect to C-balance in soil, removal of straw does not mean removing all C or nothing, but 30% of C or nothing
- **Estimated losses: up to 20%: on field + pressing**
up to 10%: transportation + storage
- **Methods for grain collection are currently changing, leaving higher stems and reduced amounts of straw**
 - ➔ can we expect again a change of collection systems towards increased yields of straw with an enhanced industrial demand of straw?
- **„Smooth evolution“: farmers are going to change their seeding and harvesting dates**
 - ➔ influences on cropping and harvesting methods to expect?

Expert Consultation „Cereals Straw Resources for Bioenergy ...“, Pamplona, 18.-19.10.2006, Report Session 2, Dr. Doris Schieder

1. Production of Straw in EU25 – Current Situation

Aspects of straw harvesting

- **Aspects of farmers (results from France):**
 - Work force planning must leave time for straw harvesting;**
 - Farmers have learned about the importance of C-balance in soils, but most of them are more sensitive on the price payed for straw than on environmental aspects**
 - ➔ are there problems on C-balance to be expected if straw firing in bioenergy plants increases?
 - ➔ there is need to provide new informations for farmers

Expert Consultation „Cereals Straw Resources for Bioenergy ...“, Pamplona, 18.-19.10.2006, Report Session 2, Dr. Doris Schieder

2. Restricting factors on the availability of straw

- **Annual variations in yields due to climate conditions**
- **Regional differences in yields:**
productivity in Europe: Central and North > South
- **Competitive use of straw for agricultural and industrial purposes**
- **Annual and regional variations in the demand of straw for agricultural and industrial utilization**

Expert Consultation „Cereals Straw Resources for Bioenergy ...“, Pamplona, 18.-19.10.2006, Report Session 2, Dr. Doris Schieder

3. Technological aspects of straw combustion

Straw pellets

- **Fabrication of pure straw pellets is technical feasible; utilization in industrial bioenergy plants has been successfully demonstrated in Denmark**
- **Problems concerning the quality of ashes and emissions are expected for the domestic use of pure straw pellets**
→ mixed pellets of wood and straw (10-20% straw)?

Co-firing of whole crops and straw

- **Technically feasible, experiences available (Ely-plant, UK: straw + 25% miscanthus)**
- **Well defined constant mixtures are required**
- **Amount of co-substrates is limited to prevent ash troubles, burner problems, etc.**

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4. Competition and market organisation

Competitive uses

- Soil return
- Cattle breeding: 1,5 Mg/a straw per unit of cattle
- Horticulture
- Industrial production: paper, panels, mushrooms, ...

Demand of straw for competitive uses

- Total amount of straw used by competitors depends on the local conditions
- Lack of data concerning the actual demand of straw for competitive uses

Expert Consultation „Cereals Straw Resources for Bioenergy ...“, Pamplona, 18.-19.10.2006, Report Session 2, Dr. Doris Schieder

4. Competition and market organisation

Market situation

- The competitive situation depends on local conditions and may change from year to year depending on the annual straw yields
- The market for straw is not yet organised, there is only a limited trans-regional trade
- „Abnormal“ years, e.g. with low yields, may cause local intermittent high price levels: farmers tend to retain straw in order to influence prices (e.g. experiences from UK)
- New technologies like “ Biomass-to-Liquid (BTL)“ may become competitors to straw-fired power plants (e.g. 5 big BTL-plants planned in Germany by Choren and Shell); however, the BTL-technologies require high capital costs and are not yet technically mature → plant capacities of approx. 1 mio. t/a biomass! → large haul distances for raw material supply!

Expert Consultation „Cereals Straw Resources for Bioenergy ...“, Pamplona, 18.-19.10.2006, Report Session 2, Dr. Doris Schieder

4. Competition and market organisation

Market situation - challenges

- Organisation of straw markets required
- Data collection and analysis on straw demand of current and future competitors required
- Power plants: contracting to ensure raw material supply

Expert Consultation „Cereals Straw Resources for Bioenergy ...“, Pamplona, 18.-19.10.2006, Report Session 2, Dr. Doris Schieder

4. Competition and market organisation

Contracting

■ General situation:

Power plants often have long-term contracts for power-supply
→ long-term contracts for straw-supply required

For farmers a balance between security of income (long-term contract) and flexibility is more reasonable
→ advise for farmers not to contract 100% of their straw yields

■ Example Sanguesa plant, Spain:

- Commitments with farmers for 10 years;
- Contract on the average yield of the area
- Prices defined at the beginning of the contract

Expert Consultation „Cereals Straw Resources for Bioenergy ...“, Pamplona, 18.-19.10.2006, Report Session 2, Dr. Doris Schieder

5. Summary



- **Local differences of yields and of straw utilization pathways within the EU**
- **Still not enough data available of straw potentials on the regional and local level**
 - ➔ **data Collection on straw quality and availability at the regional and local level (e.g. initiative towards Eurostat/FAO to include straw statistics in agricultural data basis?)**
- **Straw demands of current competitors are not sufficiently known**
- **Potentials of future competitors are difficult to estimate**
- **Optimization of the harvesting and transportation chain required**
- **Markets for straw have to be organized**

Expert Consultation „Cereals Straw Resources for Bioenergy ...“, Pamplona, 18.-19.10.2006, Report Session 2, Dr. Doris Schieder

INTRODUCTION SESSION 3

Cereals straw for bioenergy:
Industrial and logistic issues,
costs and implementation


P. Lerga, Acciona Energia, Spain






Sangüesa Straw Biomass Power Plant

Pedro Lerga
 O&M Manager Acciona Energia Biomass Department
plerga@acciona.es

Expert Consultation
 Joint Research Centre, European Commission, JRC-EC
 National Renewable Energy Centre, CENER, Spain
"Cereals Straw Resources for Bioenergy in the European Union"



Sangüesa Biomass Power Plant

Index

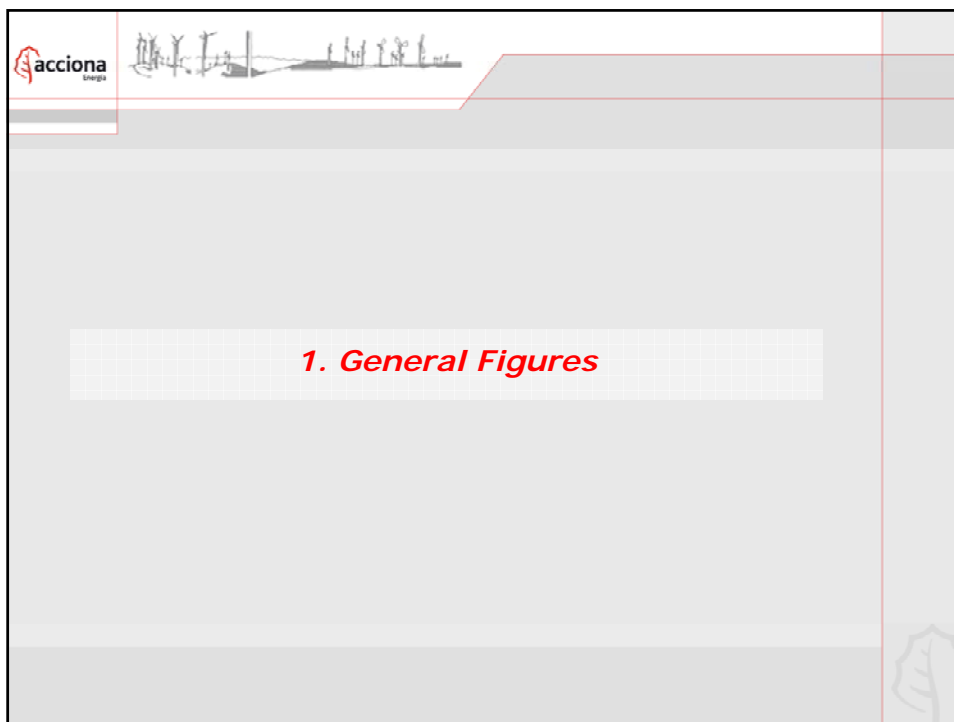
1. General Figures

2. Process

3. Estrategies

4. R&D Projects

5. Final Conclusions



The slide features the Acciona Energía logo in the top left corner and a stylized illustration of a wind farm in the top center. The title "1. General Information" is in the top right. The main content is a table with a red header row and gray data rows.



25 Mw net power plant	
• Site:	Sangüesa (Navarra province)
• Net power (MW):	25
• Area (m ²):	100.000
• Main fuel:	Straw and corn stover (forest residue is an optional fuel not installed now)
• Yearly fuel consumption (Tm) :	160.000
• Yearly energy (GWh):	200.000
• Investment (M €):	50
• Employees:	26 direct –on site–, and up to 105 indirectly



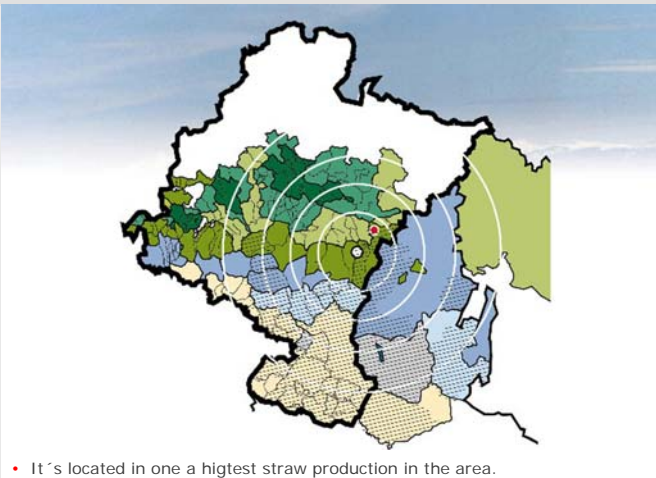

1. General Information



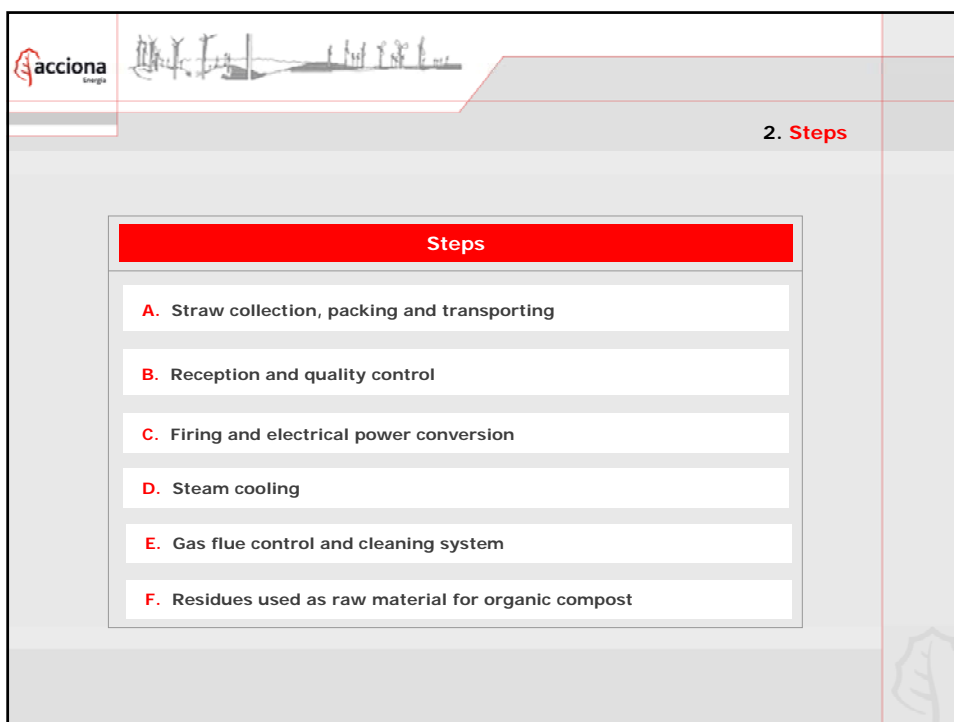
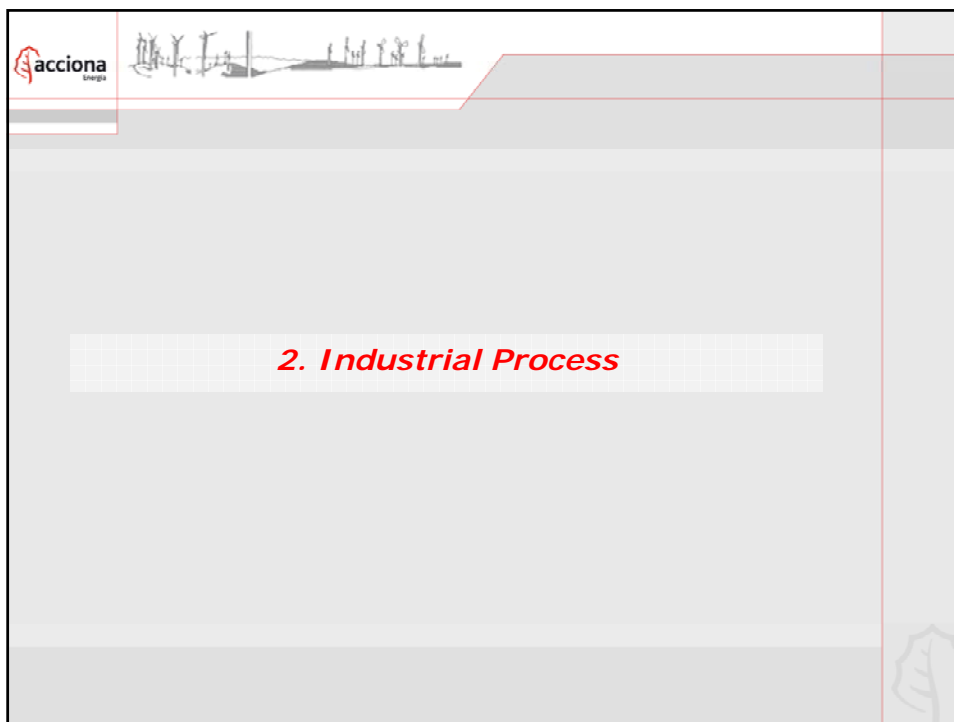
Aerial view of the site

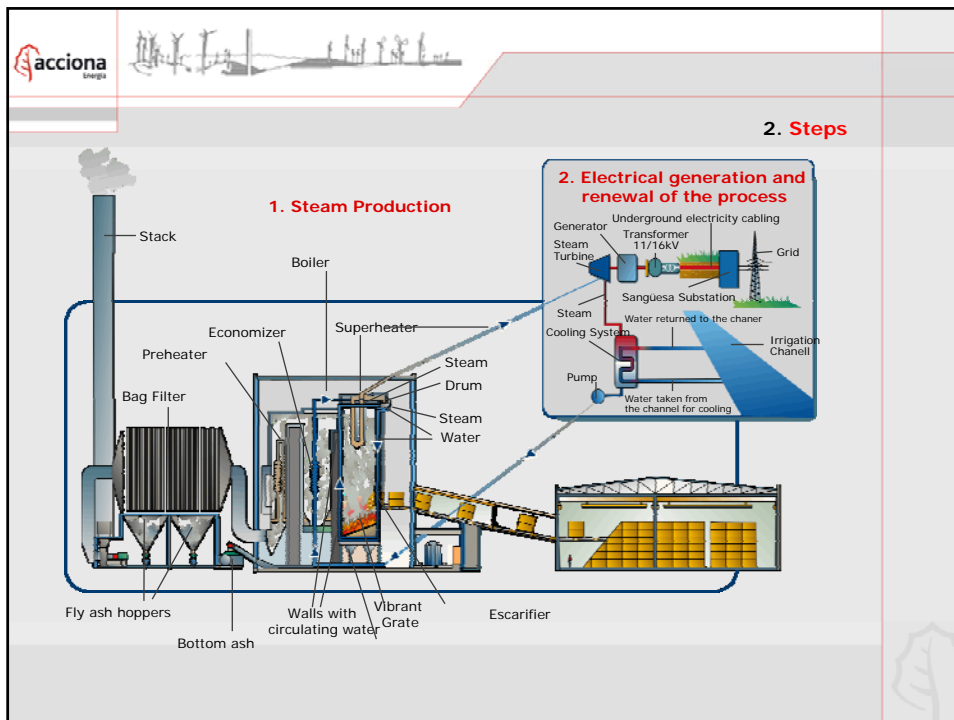





1. General Information



- It's located in one a highest straw production in the area.












2. Steps

A. Straw collection, packing and transporting





- Bales stacking with wagon
- Stack on the field

2. Steps

A. Straw collection, packing and transporting



- Warehouse entrance



2. Steps

B. Reception and quality control



- Reception of the fuel, controlling weigh and moisture level



2. Steps

B. Reception and quality control



- Transport system. Open conveyor, wagon area, close conveyor and at the the top strings are cuttered and the bales are uncompressed.



2. Steps

C. Firing and electrical power conversion

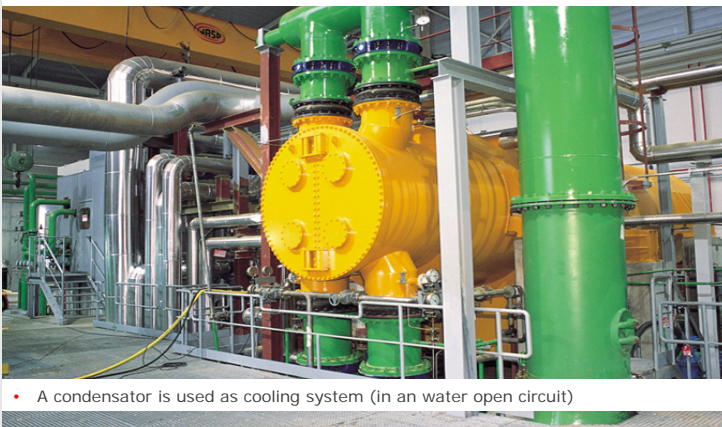


- Firing straw is use to obtain steam. Nominal conditions of steam are 32 Kg/s, 540°C and 90 bar.
- Efficiency of the plant is 31% (electrical net power / calorific net power)





2. Steps

D. Steam cooling




- A condensator is used as cooling system (in an water open circuit)





2. Steps

D. Steam cooling (water returned to the channel)




- In nominal condition, we returned it 10°C warm-up to the irrigation channel,

2. Steps

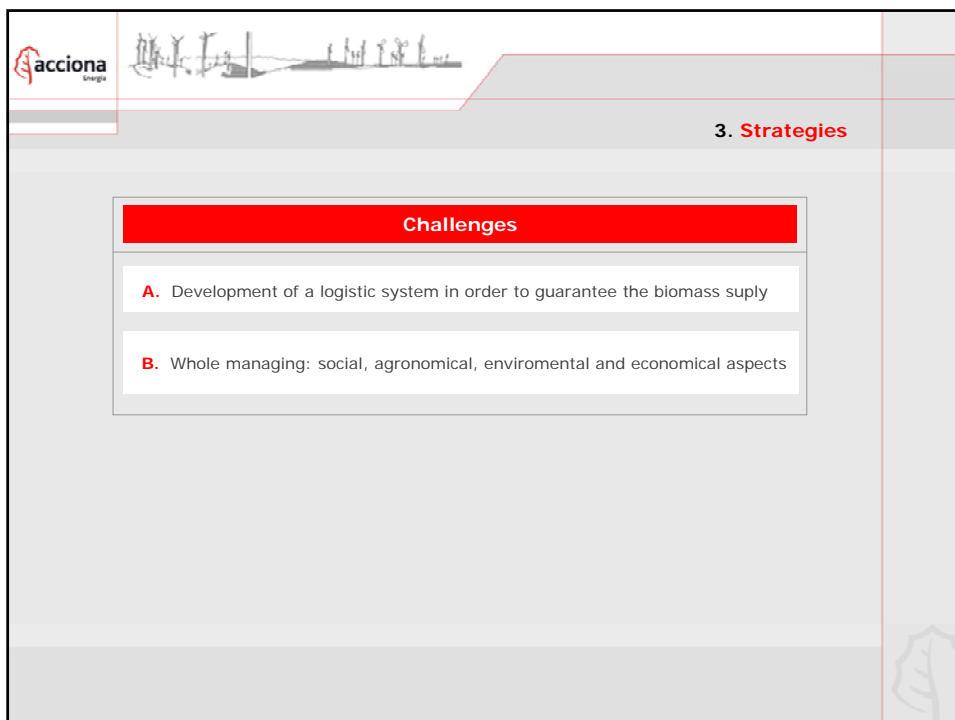
E. Gas flue control and cleaning system





- A bag filter is used as cleaning system
- Monitoring and controlling gas emissions.

F. Residues are used as raw material for organic compost

- All ashes (fly and bottom) are given to a authorized company to use as a component in organic compost.







3. Strategies

A. Fuel Logistic and supply

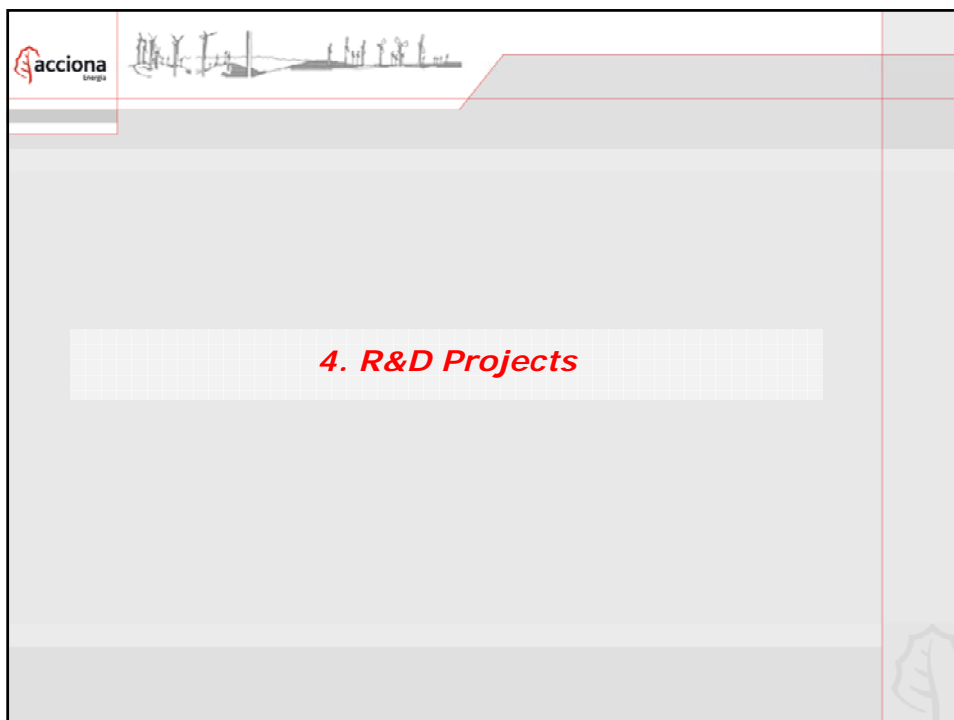
- Nowadays fuels are:
 - **Agriculture and forest residues** (herbals 100% and forest in the future)
 - **Energetic Crops** (in development)
 - **Others...**
- In case of agriculture and forest residues, it's necessary to optimize the supply (quantity, quality and all technical requirements)
- Energetic crops is necessary to develop R&D in all aspects (agronomic, packing and processing, logistic, energetic and enviromental)



3. Strategies

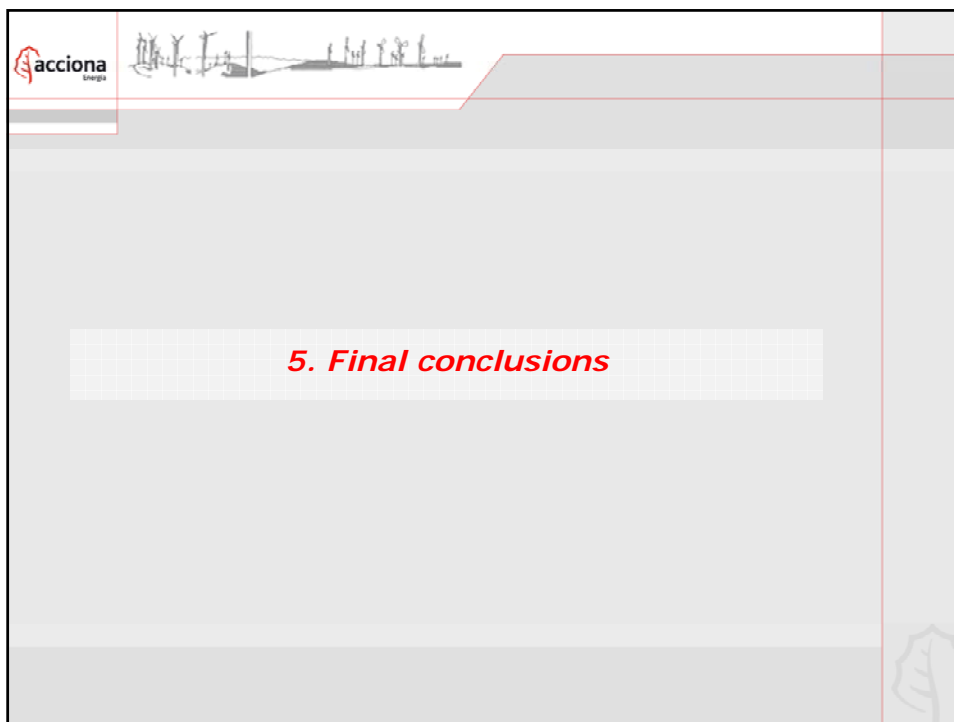
B. Whole managing

- Aspects to consider:
 - 1. Internals**, choosing the optimum of couples:
 - Fuel-residues managing
 - Logistic/Plant size
 - Site characteristics
 - 2. Externals:**
 - Positive regulations
 - Tariffs and bonus



This slide continues the "4. R&D Projects" theme. It includes the Acciona logo and wind farm illustration at the top. The title "4. R&D Projects" is positioned in the top right corner. A red header box contains the text "R&D Acciona involved in projects". Below this, three project entries are listed in white boxes:

- **HIAL Project** . Improvement of vibrant grate boilers firing high alcalis content biomass (2001-04): Expired.
- **BIOELECTRICITY CROPS Project**. Agronomic, logistic, energetic and economical aspects using diferents energetic (2003-06): Expired.
- **PSE-CULTIVOS** Analys and evaluation of diferent energetic crops in Spain (2005-12): Running.



The slide features the Acciona logo in the top left corner and a stylized illustration of a wind farm in the top center. The title "5. Conclusions" is in the top right. The main content is a white box with a red header "Un buen ejemplo para seguir avanzando" and two bullet points. A faint tree icon is visible in the bottom right corner.

5. Conclusions

Un buen ejemplo para seguir avanzando

- Sangüesa power plant is a good example to follow how with agriculture residues (straw) we can afford:
 - Electrical power (energy)
 - With incomes for farming sector
 - And with positive enviromental aspects
- And for all those reasons it 's necessary to work hard in order to increase for 2010 from nowadays 345 MW instaled up to 1.695 MW (Recomended in PER document 2005-2010).



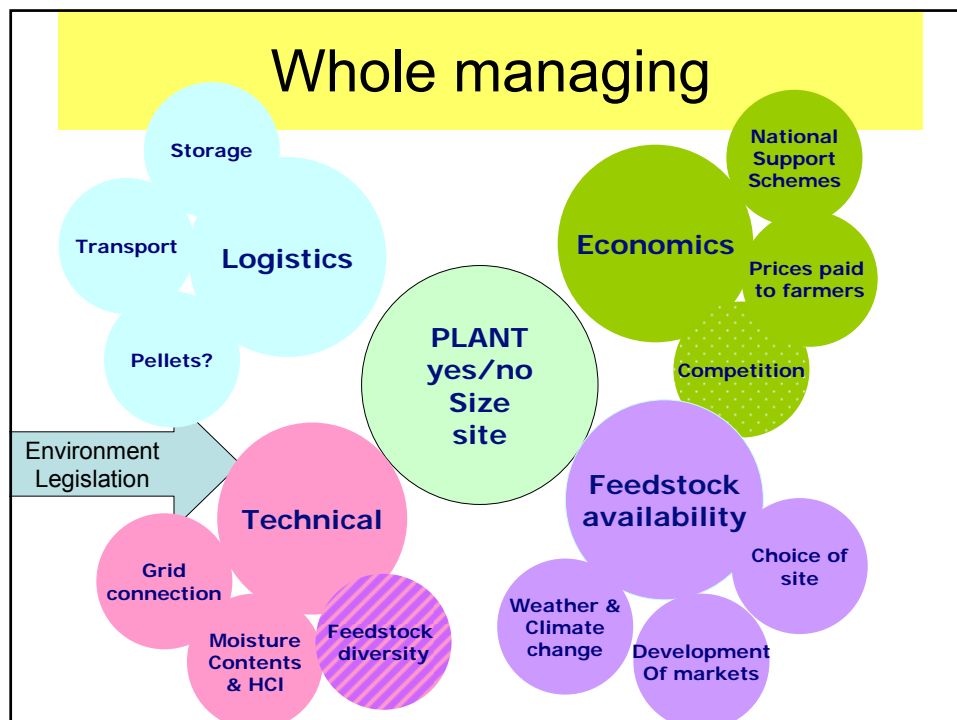
REPORT SESSION 3

Cereals straw for bioenergy:
Industrial and logistic issues,
costs and implementation

*T. Wiesenthal,
European Commission, Joint Research Centre
Institute for Prospective Technological Studies*

Report on session 3 Industrial and logistical issues, costs and implementation

JRC/CENER expert consultation
Cereals Straw Resources for
Bioenergy in the European Union
T. Wiesenthal - IPTS



Logistical Issues

- Transport logistics crucial
 - Limit the plant size
 - Collection radius of up to 90 km
 - Makes a high share of fuel costs (40 €/t total, 6 € to farmers, rest to transport (12 €), baling (18 €) etc
 - Are pellets an option?
 - High prices (market price ca 70€/t ?)
 - Lower on-side emission
- Site characteristics important
 - 80.000 ha needed for Sangüessa plant
 - 500 t per day
 - Aim at low moisture content (< 25%)
 - Diversify feedstock

Logistical Issues

- Size is thus site-specific
 - Optimal 10-15 MW, max. 36 MW
 - 1.8 Mio £ per MW_{el}
- Storage is an important aspect
 - Large volumes involved as only 2 month harvest window for straw
 - Optimal storage size difficult to determine: fire risk, protection against rain etc.
 - Storage on plant site only limited (range of days) due to daily volumes needed (500 t per day)

Technical Issues

- High availability (93%)
- Feedstock quality (moisture) impacts the combustion. Also HCl problem with coastal straw.
- Broad feedstock use worth exploring
 - Vulnerability to market change, short term weather and long-term climate change
 - Already possible within limits ($< 25\%$ blend)
 - Necessary to standardize the fuel input and adapt to different fuels of boiler, emission control and pre-processing
 - Maximise moisture content straw: 25%
- Grid connection
 - Rural sites, often limited grid capacity
- Optimisation of burning process
 - E.g. HIAL project- high alkali biomass firing

Economical Issues

- Straw is a by-product
 - Straw availability depends on the development of agricultural markets, CAP, climatic conditions
- If straw becomes a „main product“
 - Then other feedstock (perennial grasses, SRF) might be more efficient
 - However, prices of energy crops much higher (order of 100€/t compared to some 40€/t for straw)
- Feedback of higher demand on prices
 - Does burning straw then remain competitive?
 - Limit risk with long-term (10yrs) contracts?

Economical Issues (2)

- Competition with e.g. ligno-cellulosic ethanol
 - May offer better prices to farmers
- Development of support schemes and targets
 - National Premium feed-in tariffs (ca 30% subsidy)
 - National/EU Renewables 2020 targets

Implementation Issues

- Farmers may be reluctant
 - Environmental concerns
 - Traditional thinking
 - No ideal match between picking up straw quickly and demand
- Legislation may need to be adapted
 - E.g. for bringing ashes back to the field
- Process not steered by plant owners
 - As long as dependant on a by-product

EXPERT CONSULTATION
CONCLUDING REMARKS

W.Elbersen
Agrotechnology and Food Innovations
Wageningen University



Cereals Straw Resources for Bioenergy in the European Union CENER/JRC Closing remarks

Wolter.Elbersen@wur.nl

Pamplona October 2006



Bioenergy at WAGENINGEN UR

WAGENINGEN UR



0. EU straw assessment

- I thought they had taken almost everything into account!
 - They haven't
- How do local straw firing plants compare to making a fuel for export (pellets, pyrolysis oil, torrefaction)?:
 - Larger and more efficient (coal) or
 - Better use the heat (small and specific) matching infrastructure
 - Larger part of potential can be used
 - Less bulky transport?
 - If renewable heat is valuable it may change the whole picture?!
- Infrastructure limits logistic possibilities

WAGENINGEN UR



1 General thoughts

- Straw is still generally an underutilised resource (for energy but also for other uses). Information is needed to optimise the use and ascertain the potential. Which chain is the best in mobilising the resource?
- Soil Organic Matter:
 - Reducing SOM is easy - Increasing SOM is hard and slow
 - Organic material needs to be applied for better quality SOM (bacterial activity, labile SOM?): ploughing energy, water retention, water infiltration, seed emergence)
 - Net value of straw as SOM = 8 to 80 €/ha/ton
 - Potential is 25 to 50% of total straw? 1 in 2 or 3 years?
 - Interaction with compost, manure and digestate?
- Farmers:
 - Even if there is a market farmers will only supply part of the straw (why? Infrastructure, time?, perception? price? machinery?) Or is it just bad statistics?
 - It is a buyers market -> Straw is not for free! If there is a market for straw the farmer will want extra money

WAGENINGEN UR



2 General thoughts

- Uses of straw:
 - The previous use of straw has often been less than current use for energy
 - Does straw amount diminish due to dwarf variety use?
 - Competition is not mapped well
 - We need statistics !!!
- Good statistics of biomass flow are needed:
 - Primary and secondary by-products are more relevant than most people think!!
 - Any ideas about indicators? (Biomass utilisation and biomass utilisation efficiency)
- Energy crops:
 - Biomass is not just energy crops: On the contrary! Most biomass is a by-product!
 - By-products first!
- Size of plants is a challenge
 - Very large plants at seaside or river?
 - Small plants near heat demand?

WAGENINGEN UR



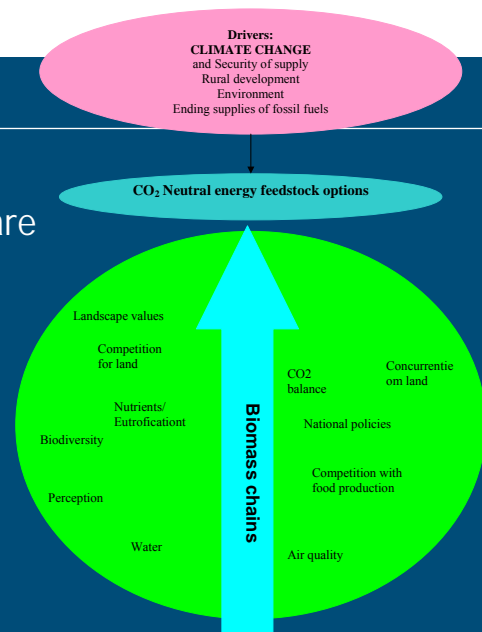
3 General thoughts

- Sustainability:
 - Overall management does not change if straw is used -> negative impact appears limited; even positive effects:
 - No-till methods require straw removal! (synergy)
 - Do soil (EU or national) regulations prevent detrimental effects of too much straw removal or is it too site dependant to regulate?
 - We need a monitoring system
- Ash
 - Regulations prevent return
 - Quality can be a problem for re-use
- Main challenge of the energy plant is biomass supply and logistics not plant operation (93% operation)!
- Quality of biomass can be a manageable problem: Ash behaviour – forest residues or additives help
- Subsidies?

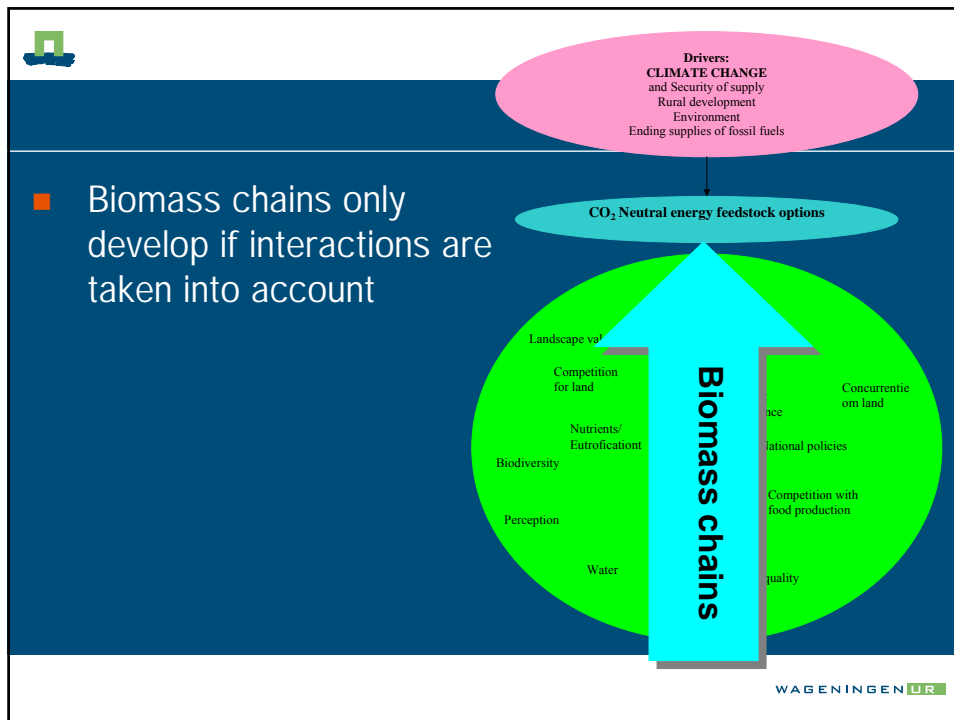
WAGENINGEN UR



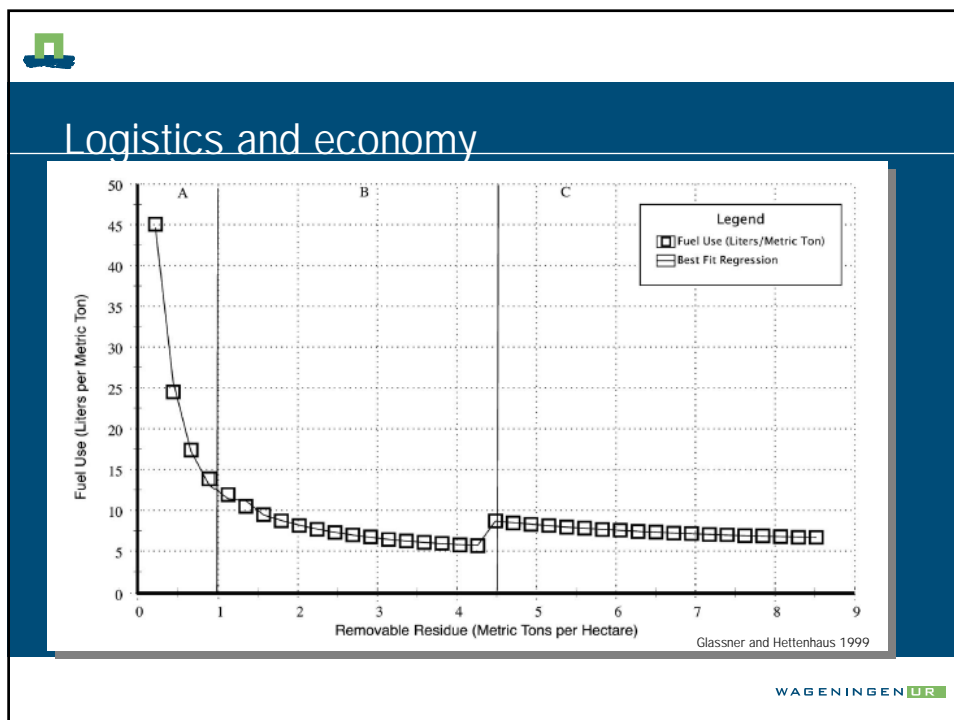
- Biomass chains only develop if interactions are taken into account



WAGENINGEN UR

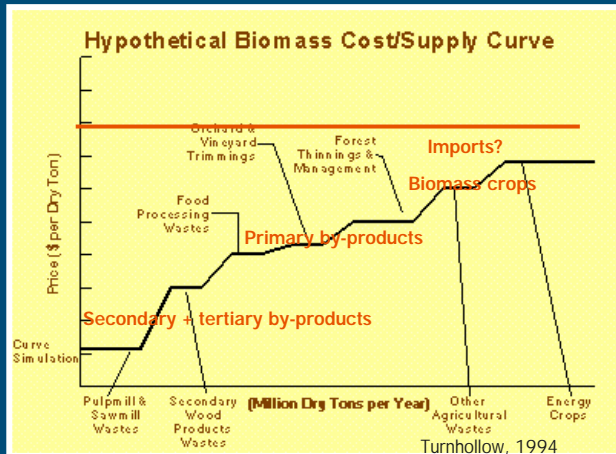


- Biomass chains only develop if interactions are taken into account





Byproducts and/or dedicated crops?

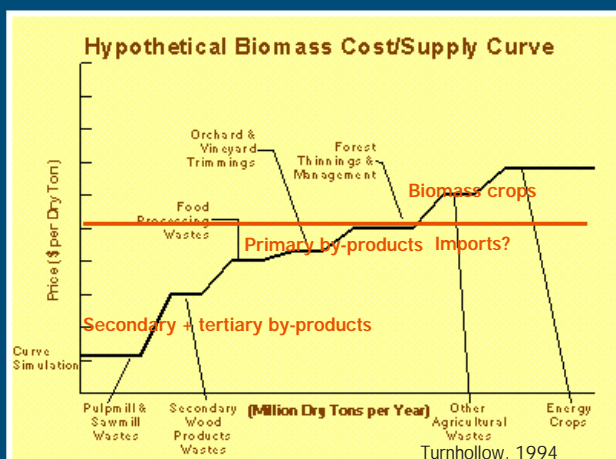


- Tertiary by-products
- Secondary by-products
- Primary by-products
- Dedicated crops
- (Imports)

WAGENINGEN **UR**



Byproducts and/or dedicated crops?

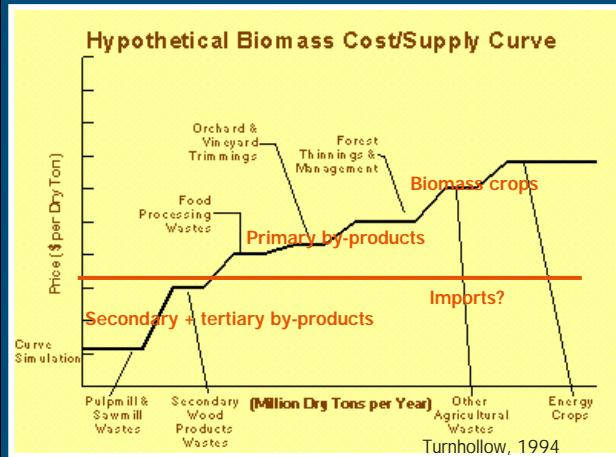


- Tertiary by-products
- Secondary by-products
- Primary by-products
- Dedicated crops
- (Imports)

WAGENINGEN **UR**



Byproducts and/or dedicated crops?



- Tertiary by-products
- Secondary by-products
- Primary by-products
- Dedicated crops
- (Imports)

Expert Consultation Motivation

***“Cereals Straw Resources for Bioenergy
in the European Union”***

Expert Consultation

“Cereals Straw Resources for Bioenergy in the European Union”

Place: Pamplona, Spain.

Date

18 and 19 October 2006 (1 day meeting starting 18 october 2pm, followed by a technical visit on 19 October)

Background

This Expert Consultation is organised by the Institute for Environment and Sustainability of the Joint Research Centre of the European Commission IES JRC (www.jrc.cec.eu.int), in cooperation with CENER, the National Renewable Energy Centre of Spain, (www.cener.com).

Motivation

The European Union has set a target of 12% of total energy consumption to be produced from renewable energies. In addition, in 2010 renewables shall contribute 21% of gross inland electricity consumption and 5.75 % of all transport fuels will have to be biofuels. The use of biomass in transport fuel, heat and electricity production will have to increase substantially to meet these targets. In order to reach these targets, at the end of 2005, the European Commission has issued a Communication on a Biomass Action Plan and its corresponding Impact Assessment (see http://europa.eu.int/comm/energy/res/biomass_action_plan/green_electricity_en.htm).

Policy discussions for European renewable energy targets beyond 2010 have commenced. In addition to the existing European legislation on electricity from renewables and use of biofuels, a Directive on heating and cooling from renewables is in preparation.

This Expert Consultation is organised within the framework of the activities of the Scientific and Technical Reference System on Renewable Energy and Energy End-Use Efficiency (Renewable Energies Unit of the Institute for Environment and Sustainability, Joint Research Centre, European Commission, see <http://streference.jrc.cec.eu.int>). Straw from cereals is already used at operational level for bioenergy purposes, for example in Spain, United Kingdom and Denmark. The investment in new plants is being considered in the case of other European countries. This Meeting aims specifically at a technical discussion regarding the collection and use of straw from cereals in the European Union. It will bring together a small group of researchers and professionals in the energy field in order to develop expertise, exchange information and improve data collection mainly on 1) assessment of agronomic & environmental constraints related to the harvesting of straw from cereals, 2) assessment of straw resources and competitive uses 3) practical problems related to the industrial use of straw for bioenergy purposes.

Expected outcome

Prior to the Workshop, a Background Technical Document and Agenda will be sent for information by the Meeting organisers to the Expert Consultation participants. This Expert-Consultation will be organised in such a way that instead of a sequence of presentations, a large space will be given to interactive technical discussions.

The Workshop aims at collecting the state of knowledge and at answering the following questions:

1. Which **environmental and agronomic constraints** have to be taken into account when harvesting straw from cereals in the European Union ? Can some rules be derived from soil characteristics and subsequently GIS mapped at local, regional, national or European levels ? What scale is possible and necessary for the mapping of straw resource potential in the European Union ? What are the effects of straw removal on soil characteristics, for example on soil carbon content and nutrients availability or on soil erosion risk ? What are the main farming practices related to straw in the main producing cereals regions ?
2. What are the **main uses of straw from cereals** competing with its use for bioenergy ? Can these competitive uses, for example use in animal rearing, mushrooms cultivation, horticulture..., be quantified at local/regional/national levels or derived from European data-bases ? What are the main straw resources in addition to wheat and barley ? Which institutions are in charge of collecting data on the use of straw or in a position to provide information on this ?
3. What are the **costs and practical problems of implementation to be faced** when developing the industrial use of straw from cereals for bioenergy purposes ? What are the constraints in terms of cost of straw, logistics, distance of collection, storage, harvest period, perceptions of farmers, security of supply ? CHP and heat is an attractive use for straw, but its application is limited to where there is a use for the sufficient heat to make an economic size of plant. How can we assess the opportunities in the European Union ?

The outcome of the Expert Consultation will be summarized in proceedings prepared by the Meeting organisers, focussing on the 3 questions above and based on the input provided by the Meeting participants.

Experts:

This Workshop is intended to include 20 participants maximum in order to allow discussions. Experts will be invited from European Union Member States or regions active in the use of straw from cereals for bioenergy, for example from Spain, United Kingdom, Denmark, France, Germany and Lithuania. Experts will originate mainly from agricultural and environmental institutes, renewable energy institutes and research centres and energy companies.

Of special interest for this meeting is expertise related to:

- Agronomic knowledge on cereals, cereals straw and soil characteristics,
- Farming practices and environmental impacts of straw harvesting,
- Operation or planning of bio-energy plants using straw.

-Contacts:

- J.F.Dallemand (Bioenergy, Scientific and Technical Reference System on Renewable Energy and Energy End-Use Efficiency, Joint Research Centre of the European Commission)

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Expert Consultation

**Joint Research Centre, European Commission, JRC-EC
National Renewable Energy Centre, CENER, Spain**

“Cereals Straw Resources for Bioenergy in the European Union”

18- 19 October 2006

Agenda

18 October 2006, Afternoon,

Session of Introduction

Chair: I.Echeverria CENER, J.F.Dallemand, European Commission, Joint Research Centre

1.30pm-2pm,

Welcome, *I.Echeverria, CENER Biomass Unit*

Introduction of participants

Objective of the meeting

2pm-3pm, GIS based assessment of cereal straw resource assessment in the European Union,

M.Suri, R.Edwards, European Commission, Joint Research Centre

First Session

Cereals straw for bioenergy: Environmental and agronomic constraints

Main topics: Environmental and agronomic constraints to take into account. Soil characteristics and GIS mapping at local, regional, national or European levels. Effects of straw removal on soil characteristics, for example on soil carbon content and nutrients availability or on soil erosion risk. Main farming practices related to straw in the main producing cereals regions...

Chair H.P.Pierr, University of Applied Sciences, Eberswalde, Germany

Rapporteur D.Powelson, Rothamsted Research, United Kingdom

3pm-3.20pm, Session Introduction

3.20pm-4.30pm, Discussion

4.30pm-4.45 pm Coffee break

Second Session

Cereals straw for bioenergy and competitive uses

Main topics: Main uses of straw from cereals competing with its use for bioenergy. Quantification of competitive uses and available data. Identification of main straw resources in addition to wheat and barley. Identification of institutions in charge of collecting data on the use of straw...

Chair : F.Labalette, GIE ARVALIS/ONIDOL

Rapporteur D.Schieder, Technical University of Munich, Germany

4.45-5pm, Session Introduction

5pm-6.15pm, Discussion

19 October

Third Session

Cereals straw for bioenergy: Industrial and logistic issues, costs and implementation

Main topics: Costs and practical problems of implementation to be faced when developing the industrial use of straw from cereals for bioenergy purposes. Constraints in terms of cost of straw, logistics, distance of collection, storage, harvest period, perceptions of farmers, security of supply... Resource availability and size of plant...

Chair: P. Lerga, Acciona Energia, Spain

Rapporteur T. Wiesenthal, European Commission, Joint Research Centre

9am-9.20am, Session Introduction

9.20am-11.15am, Discussion

11.15am-11.30am Coffee break

Fourth Session

Reports and Conclusions

Chair: J.F. Dallemand, European Commission, Joint Research Centre I. Echeverria CENER

11.30 am-12.15, Reports Sessions 1 to 3 (10 minutes each)

12.15, 12.30, Concluding Remarks, *W. Elbersen, Wageningen University*

12.30 End of the Workshop

Afternoon

Technical visit to Sanguesa plant.

Expert Consultation

**Joint Research Centre, European Commission, JRC-EC
National Renewable Energy Centre, CENER, Spain**

“Cereals Straw Resources for Bioenergy in the European Union”

18- 19 October 2006

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**Expert Consultation
Background Document**

***“Cereals Straw Resources for Bioenergy
in the European Union”***

GIS-BASED ASSESSMENT OF CEREAL STRAW ENERGY RESOURCE IN THE EUROPEAN UNION

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ABSTRACT: We used statistical and GIS data for EU25+2 to assess the energy potential of straw from wheat and barley. First the straw produced was calculated on NUTS2 level taking into account variations in yield. Next the major competitive uses were subtracted. The net straw availability data were then disaggregated using CORINE land cover for 5x5km grid. We chose the highest resource density on this map to locate the first 120 MW_{th} (38 MW_{el}) power station, then proceeded to find optimal locations of further power stations until their straw supply radius exceeded 50 km. The generating costs for the identified locations of 67 power stations were estimated to rise from 68 to 73 €/MWh as straw transport distance increased.

Keywords: straw, resource potential, electricity generation

1 INTRODUCTION

The amount of biomass available for energy use depends not only on the total resource, but also upon how much can be economically and logistically delivered to processing plants.

Geographical Information Systems (GIS) have already proven their capability to resolve spatially-determined issues, and in the field of bioenergy the map-based assessments are also emerging rapidly (see [1-5]).

We have applied the existing European-wide statistical and GIS data in order to assess the technical potential of straw from wheat and barley in the 25 European Union countries and 2 Accession States (Bulgaria and Romania).

While not all the steps have been finalized, this paper presents a straw-for-energy map for the EU25+2, and an example of how much can be logistically and economically exploited for plant of a certain capacity, together with an estimate of the associated electricity generating costs.

2 DATA

2.1 Statistical data

The data are available from Eurostat [6] for EU25+2 at level 2 of NUTS administrative regions. The following data were used (representing the year 2003, except for Spain – 2002 and Bulgaria – 2001):

- wheat (soft and durum), and barley: yields, area and production;
- cattle production.

2.1 GIS data

The following GIS data were used:

- CORINE Land Cover 2000 (CLC2000). The data represent the state of the European land cover around the year 2000 [7];
- GISCO database – the administrative boundaries at the scale 1:1 mil. (NUTS regions at level 2, for Germany and UK only level 1).

2.3 Complementary data

We have collected a wide range of studies on straw-for-energy, including papers, national reports, regional studies and direct communication with research and regional authorities. The support information was

collected from the following countries and regions: Bulgaria, Czech Republic, Denmark, France (+region Centre), Germany, Hungary, Ireland, Italy, Lithuania, Poland, Romania, Slovakia, Spain, and England. We focused on obtaining the following information:

- agrotechnical and environmental aspects of straw collection to soil fertility;
- competitive use of straw;
- energy-technology options;
- transport costs;
- case studies on existing bioenergy installations.

3 METHODS AND RESULTS

3.1 Straw potential at the level 2 of NUTS regions

First, we estimated the straw yield (*straw*, tonne/hectare of arable land) as a function of the grain yield (*grain*, tonne/hectare). S.S. de Vries [8] gives an empirical range of harvest indices (grain/above-ground biomass) for three ranges of the above-ground biomass. From this we deduced straw/grain ratios as a function of grain yield: this discontinuous relation was smoothed into a convenient function:

$$\text{straw} = \text{grain} * 0.769 - 0.129 * \arctan((\text{grain} - 6.7)/1.5)$$

This indicates that the straw/grain ratio falls from a maximum of 0.94 to a minimum of 0.62 as the grain yield increases. Although this formula is based on data for wheat, experts have confirmed that it is approximately correct also for barley, which would be confined to the low yield, high straw ratio end of the curve.

Then we applied this function to Eurostat statistical data (wheat and barley yields, area and production), linked with GIS NUTS2 regions. The resulting estimate of straw potential from wheat and barley at the level of regions is presented in Fig. 1.

Not all produced straw is available for bioenergy. The first two constraints that need to be quantified are environmental limitations and the competitive use of straw.

The environmental constraints should prevent collection of straw from fields where there are unfavourable soil conditions: low organic matter content, risk of degradation processes, limited water resources, and extremes of climate. In these cases ploughing back the straw into the soil helps sustain soil fertility.

However, decomposition of straw in the soil depletes soil nitrogen, making it necessary to use extra N fertilizers in the next growing season.

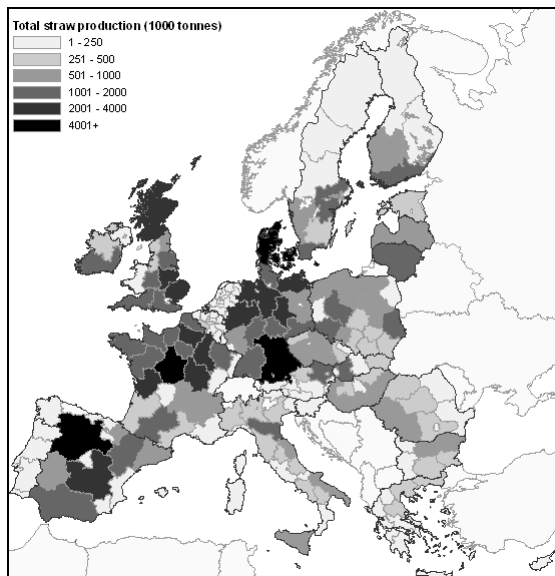


Figure 1: Straw production (1000 tonnes/region) estimated from Eurostat data at the level of NUTS2 regions (Spain – year 2002, Bulgaria – year 2001, other countries – year 2003).

Frequently, straw is considered by farmers as a burden and is either collected and left at the edges of fields, or burned. Ironically, this is more usual in Southern and Eastern Europe, where the risks to long-term soil fertility are generally higher. The possible effects of systematic straw collection on environmentally sensitive soils has to be addressed by separate studies and therefore was not considered in this work so far.

There are several uses for straw which compete in some regions with energy applications. The main competitive use is cattle bedding/litter. Significant amounts of straw are also used in horticulture, mushroom production or for industrial processes. However the information published in various international, national and regional studies is inconsistent, and often based on an expert guess with lacking documentation of the methodology and terminology. There are also a few surveys, but comparison between them is limited due to the same reasons.

It is generally accepted that cattle raising is the most important competitive use of straw. The amount of straw used per head of cattle depends on how long cattle stay indoors (which varies with climate and geography), what type of sheds are used and what is the straw availability in the region. Based on the scattered data of available studies we have estimated the straw used per head of cattle (*SUPH*, tonne/head) from total straw produced per head of cattle in the region (*SPPH*, tonne/head) by an empirical equation:

$$SUPH = 2 * (1 - \exp(-SPPH/2))$$

Using this equation, the estimated straw used per head of cattle in different regions lies between 0.1 and 2 tonnes per year. Subtracting this estimation of competitive use results in a map of the net surplus of

straw at the level of regions (Fig. 2). Some regions show a net deficit.

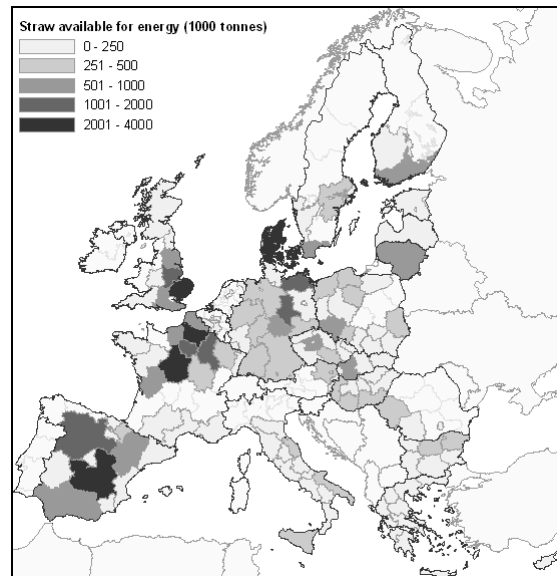


Figure 2: Net straw surplus/deficit (1000 tonnes/region) estimated from national studies and cattle breeding data (Eurostat: Spain – year 2002, Bulgaria – year 2001, other countries – year 2003)

3.2 Straw potential for grid 5x5 km

The Eurostat statistics used in the above calculations is available up to the detail of the NUTS2 regions. This information is not detailed enough for taking decisions as the use of straw for energy is partly determined by its distributed nature and transport distance (tens of kilometres). Therefore we used the CLC2000 data to spatially disaggregate the information from the statistical regions onto a regular grid with a cell resolution of 5x5 km.

The area of wheat and barley was estimated in each 5x5 km grid cell, assuming that it is distributed uniformly on the fraction of the cell devoted to the CLC2000 category 211 (arable land). Then the straw production for each 5x5 grid cell is found by distributing the net straw surplus for each NUTS2 region among its constituent grid cells in proportion to the areas of wheat and barley in each cell. This results in a more detailed map of net straw availability (Fig. 3).

3.3 Suitability of straw for large scale electricity generation

There are several pathways of conversion of straw to energy – it can be burned for electricity and/or heat, or it can be converted to ethanol or other transport fuels. In this study we have focused on localisation of large electricity power plants.

The next constraint on the availability of straw-for-energy is how much straw can be made economically and logistically available at the conversion plants. This requires knowledge of the optimum size of such a power plant. Then suitable locations for the plants can be hypothesized on the basis of the maximum transport distance, which depends on the net available straw density.

The specific capital cost of a straw-burning power plant decreases as it is made bigger, but the cost of straw

transport increases. So the generating costs show a minimum with increasing plant size. Therefore the spatial density of net straw availability in the capture area of the plant affects the optimum plant size, and the cost of the electricity produced.

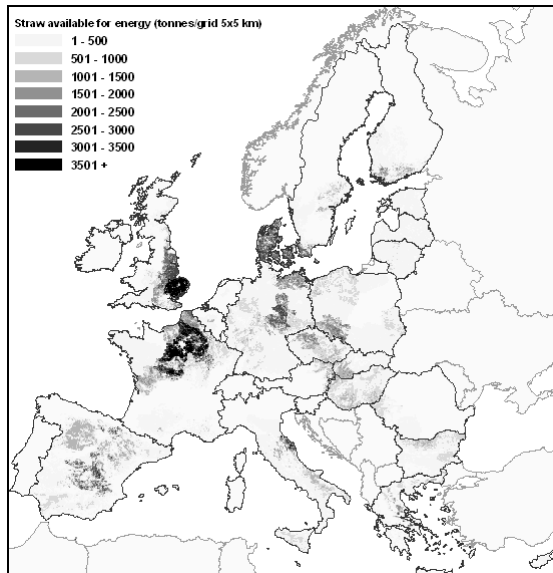


Figure 3: Net availability of straw (tonnes per 5x5 km grid cell), estimated by disaggregating the net straw availability per region (Fig. 2) using CLC2000 data (category arable land).

In the first step we have analysed a breakdown of electricity generation costs of such a power plant. We took an example of the world's biggest straw-burning power plant that is in operation in Ely (Sutton, UK) since year 2000. With an installed capacity of 38 MW_{el}, this power plant yearly consumes 200 000 tons of straw (+6% natural gas energy) that is presently collected within a distance up to 50 km. Currently the straw delivered to the gate of the power plant is purchased at a cost of 43.5 €/tonne (16% moisture).

Straw-burning power plants and the associated straw-handling infrastructure is still a developing technology: the capital cost will fall as more plants are produced. We start with a working hypothesis that within the European Union several tens of Ely-size power stations could be built. Then, according to the learning curve, with a "b" constant of 0.1, we estimate that the investment costs for each of those power plants would be of 75% of the Ely project: that means about 60 M€.

Taking into consideration an industry-standard capital charge of 15% (corresponding to a discount rate of 8%) + 4% of CAPEX for plant operating expenses, and straw collection from the 50-km radius we calculated that the electricity generation cost of those Ely-type plants would be around 71 €/MWh. Although fuel (straw) contributes 50% to the overall electricity generation costs, the calculation shows that the transport cost itself is only 5%.

We calculated the optimum plant size assuming that the capital cost of power plant scales with (MW)^{0.7} and plant efficiency increments by 9% when the plant size increases by a factor of 10 (derived from data on wood-burning power stations), the theoretical optimum size of straw-burning power plant turns out to be very large:

about 900 MW.

This means that the practical limitation to the size of the power plant is logistics. The Ely-sized power plant (38 MW) already needs about 50 heavy trucks per day delivering 20-tonnes of straw each. Due to rather limited road infrastructure in most of rural areas of Europe, this imposes a practical limit for most inland locations (larger power plants are conceivable where ship or train transport is possible). Due to this logistics limitation, we decided to consider Ely-size power plants in the following procedure to find how many straw-burning power stations could be located inland in EU25+2.

Starting with the net-straw-availability map (Fig. 3), the procedure consists of the following steps:

- Calculation of a map of collection radius for straw consumption of 200 000 tonnes of straw per year (enough for an Ely-size power plant: 38 MW) plus a reserve of 50% more straw to allow for variable yields and other difficulties.
- Identification of the most suitable candidate site (from the point of view of straw density);
- Subtraction of the straw resource from this site, and recalculation of the transport-radius map.
- Finding the next-best site, with slightly higher transport radius
- The procedure is repeated until transport radius exceeds 50 km.

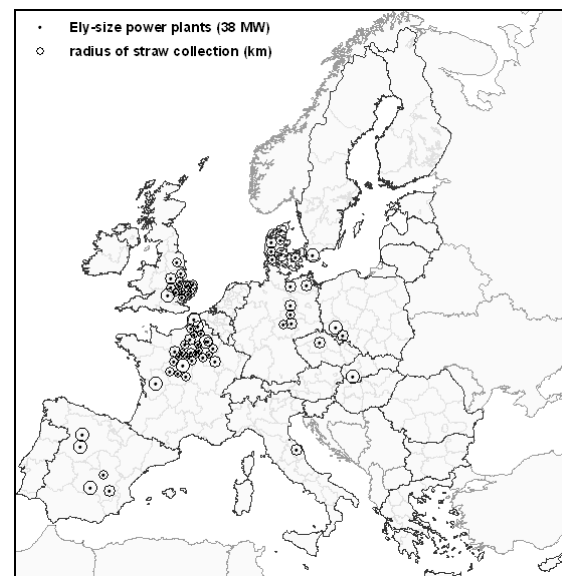


Figure 4: Theoretical localisation of 38 MW electricity generation power plants in the EU25+2 countries.

The resulting map (Fig. 4) shows that in the EU25+2 one could theoretically build about 67 Ely-sized power plants (most of them in France, UK and Denmark) with total capacity of 2.5 GW. Using this capacity the straw energy utilized would be 230 PJ (LHV thermal) out of a total net straw availability of 820PJ.

It should be noted that this estimate has only the scope to find the maximum number of power stations, not to propose particular sites, which would require much more detailed local assessments of logistics. In this case we ignore the fact that some straw is already used by the existing power plants in the UK (1 installation) and in Denmark (11 installations).

The electricity generation cost is affected by straw

density: we took the maximum transport distance to be 15% more than the collection radius. Anglian Straw, the company who supplies the Ely power station kindly told us their transport costs, and we combined this with fixed straw costs back-calculated from the delivered cost of straw at Ely. The assumptions on power station costs were as above. The resulting range of electricity generating costs at our identified locations is 68-73 €/MWh (Fig. 6).

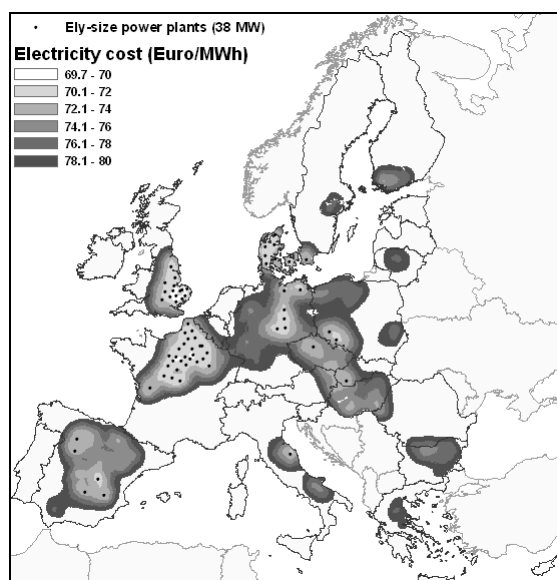


Figure 5: Effect of resource density on electricity cost, assuming theoretical location of 38MW electricity generation power plants.

4 DISCUSSION

The map on Fig. 4 indicates that in Europe there is a potential for building of several tens of power stations of the size of 38 MW. However any detailed localisation will need a set of further parameters on a more detailed scale, such as settlements structure, transport routes, availability of water for cooling, fluctuation of the straw resource, etc.

The most significant limitation for building big straw-electricity capacities (>50 MW_{el}) is logistics imposed by the daily traffic of heavy trucks shipping straw close to the power station. Plants for converting straw to biofuels are more complex and their economic feasibility depends on larger scale operation, which is probably only possible with the help of ship or train transport.

In our study the 67 electricity-generation power stations have still left out 72% of straw for small-scale applications.

There is a range of smaller applications that could be considered further in the analysis. Smaller combined heat and power (CHP) power plants are economic where there is a large enough need for the heat (factories and existing district heating). Replacing boilers for district heating and process heat in factories is probably the cheapest and most practical way to save greenhouse gases with straw. There is still potential for technological improvements in converting straw to pellets/briquettes that would allow much wider use in domestic applications. A temporary

solution would be co-firing straw with fossil fuels, normally coal.

The largest source of uncertainty in this estimate is how much extra straw should be considered in reserve. Our value of a 50% reserve of potential straw is at the low end of estimates: power companies do not like to be vulnerable to local farmers holding out for higher straw prices. Although cereals are the most profitable crops, there is still year by year resource fluctuation due to weather and other factors. Among the other factors that could also affect the straw energy economy are land use changes (set aside, organic farming), changes in crop-mix and prices development.

The study uses the best information currently available on straw supply for all EU, but could be improved with incorporation of more detailed data on particular countries or regions. In future we could consider also other sources of lignocellulosic biomass: other crop residuals and energy crops. As indicated, issues of local sustainability of straw removal have to be addressed by a separate studies. In future, we also plan to include the effects of straw trade between regions.

5 CONCLUSIONS

In this study we used consistent data and methodology to estimate total net availability of straw from wheat and barley for energy for EU25 member states and 2 candidate countries (Bulgaria and Romania). This amounts to 820 PJ.

Then we estimated how much of this straw could logistically be made available to conversion plants of about 120 MW_{th} capacity. If the plants are copies of the Ely straw-burning power station, 2.5 GW would be generated. Even with quite optimistic assumptions, this turns out to be about 230 PJ: 38% of the total: sufficient for 67 such plants. The estimated electricity generating costs associated with these plants vary with location from 68-73 €/MWh.

More of the available straw could be used in smaller CHP plants which can be economic where there is an existing need for the heat, or in heating boilers.

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**Expert Consultation
Suggested References**

***“Cereals Straw Resources for Bioenergy
in the European Union”***

European Commission

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Abstract

This document contains the Proceedings of the Expert Consultation on Cereals straw for bioenergy in the European Union held in Pamplona (CENER Headquarters) on 18-19 October 2006. This Workshop was jointly organised by the JRC and CENER and was attended by 25 experts from 10 European countries. The main sessions dealt with 1) Agro-Environmental impact of straw harvesting 2) Use of cereals straw for bioenergy and competitive uses 3) Costs and practical problems of implementation to be faced when developing the industrial use of straw from cereals.



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